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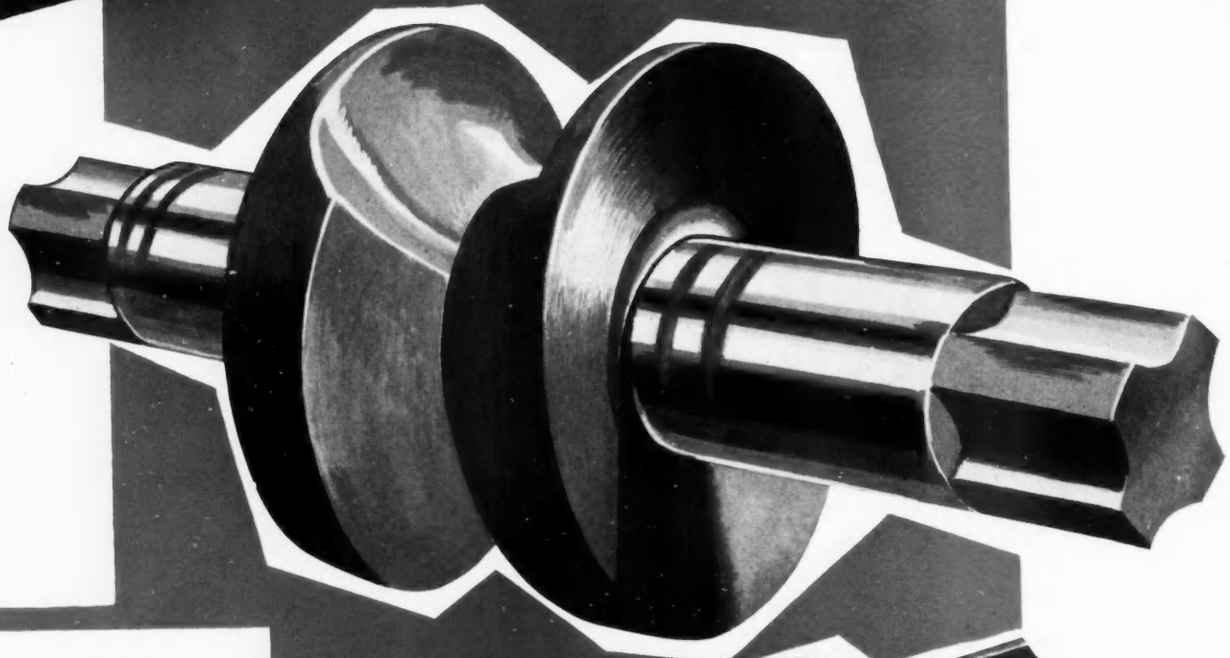

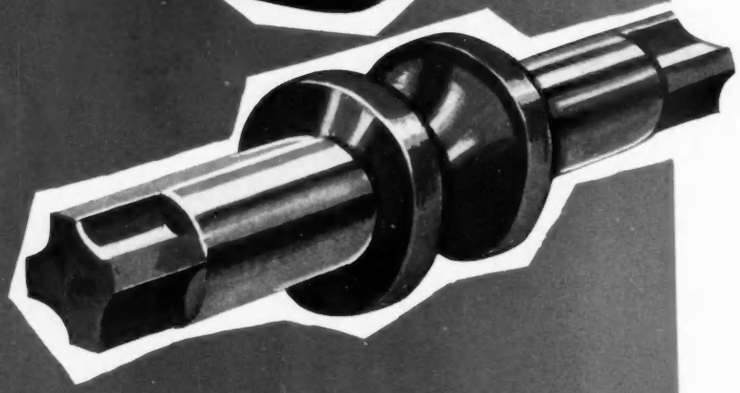

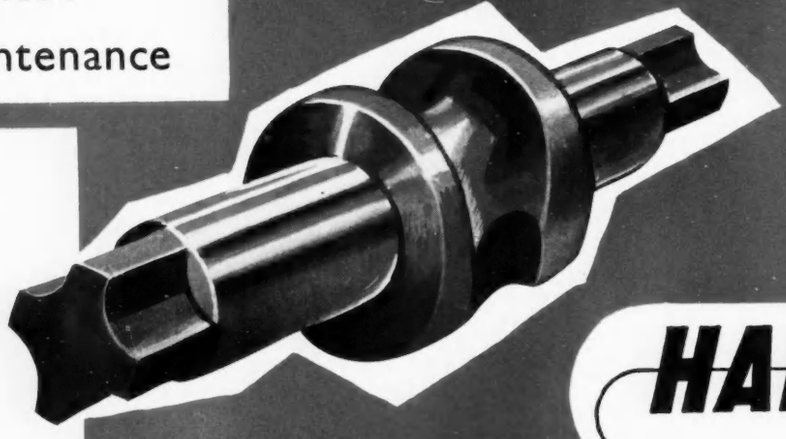

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Shifting Sands of Leadership

MANY people, if not most, want promotion. This means usually not only more money but also more responsibilities and more subordinates to look after. How many of those who want promotion have asked themselves: "Am I able to supervise and lead a larger number of people?"—"Am I able to supervise people with more education, more knowledge and experience than have those who work under me at present?"

These are some of the thoughts inspired by a one-day conference on leadership organised last week by the British Institute of Management. Professor Robert Tannenbaum of the University of California, who was among the speakers, delivered two extremely stimulating lectures followed by animated and thought-provoking discussion.

Professor Tannenbaum, who is professor of personnel management and industrial relations, refused categorically to provide a set of rules on effective leadership, and he emphasised strongly that there were no easy or simple answers. At the same time he did not confine himself to this somewhat negative approach, or hide behind a smoke screen of vague and general phrases. His words carried no aura of mystery, and phrases such as "group dynamics," "brainstorming" and "group-think"—terms that have come to be associated with the mystique of personnel relations—played no part in his address.

Effectiveness in an executive position does not depend only on the personality traits of the man who is supposed to be the leader. Personal characteristics of his subordinates are no less important. Some of us are good as managers of men but find it difficult when we have to supervise women—or the other way round. Some like as their subordinates men with high education who are articulate in speech and are quite ready to express their criticism and opinions. Others, perhaps more numerous, prefer to supervise those who accept instructions without much comment and who do not offer suggestions. Some find it difficult to cope with a secretary who bursts into tears or a foreman fuming with rage. Others get lost and perhaps lose their tempers when confronted with a calm and composed but complicated argument. How well do we know ourselves? If we were free to pick our subordinates, our colleagues and bosses, would we know with what sort of person we could work best?

Effective leadership does not only depend on the personality characteristics of the leader and those who work under him, but also on the organisational and situational context. To lead the crew of a destroyer and to manage an accounts department call for different traits and a man who is ideal in one context may not be suitable in the other. Some men, those who inspire confidence in their skill and knowledge, and who issue brief and unequivocal instructions, easily intelligible and obviously well-adapted for the purpose in hand, are good leaders in emergencies when a man of lesser incisiveness and brevity might fail. On the other hand leadership of an advisory committee or a consultative assembly requires a great deal of patience, forbearance and tact. In this context, the forcefulness and boldness of a successful military commander would be a positive disadvantage.

In all these different situations there are two important factors which determine how good we are as leaders. These are first, how well we understand others, and second, to what extent we are free to do what we know needs doing. A common cliché says that a good supervisor can put himself in the shoes of another person. Professor Tannenbaum rightly pointed out that what *I* would feel if *I* were in someone else's shoes does not matter. He is a unique human being and he is not me, nor necessarily like me. If I am to be his superior at work, or even his subordinate or colleague, it is important to know and to understand what *he* feels being in his shoes and being the precise sort of person *he* is.

It is interesting to notice that so much of what Professor Tannenbaum had to say on understanding ourselves and others bore out the views expressed by Mr. Z. M. T. Tarkowski in his previous and present series of articles published in this journal.

Understanding ourselves and others is still not enough. Many of us who have to supervise others know of the painful experience when we decide to reprimand somebody and plan exactly what to say. When a man enters the room the words so carefully prepared fail to issue forth from our mouths, the stern tone of voice and the facial expression do not quite come off; the strong attitude we had intended to adopt dissolves or does not materialise at all and the admonition or rebuke degenerates into hesitant and ineffectual chatter.

Both these, understanding ourselves and others and the ability to appreciate what we are able to do and the ability to do what we intend doing, depend on emotional maturity. The more unresolved personal problems a man has the less good is he as a leader and manager.

Cover Picture.—*The deflashing, or trimming, of a rubber moulding usually represents a high proportion of its total cost. In recent years great advances have been made due to improvements in mould and tool design and in processing techniques, but, in general, the engineer in rubber still has to provide special trimming equipment according to the job.*

(*Nurnberg photograph for* ENGINEERING)

* * *

Plain Words

We used to be a reticent nation who did not talk to one another in railway carriages. Once we had a silent service and were famous for our phlegm. We held our tongues indefinitely, but when we spoke the sound was terrible. Strong and silent were words uttered in the same breath and were almost synonymous in meaning. But times, I see, have changed.

I wonder if we are any better off. Britain does this; Britain does that: it's almost all we hear these days. We might as well be foreigners. I guess those chaps who live in the wide open spaces—the prairies and the steppes—get used to shouting; so we must raise our voices too, if only to be heard. Still it makes you wonder. Perhaps we ought to save our breath and push on with the job. What's more, it's easy to get the emphasis in the wrong place when you shout. Already there is a tendency to do the things that look good in headlines rather than the things that look good in a balance sheet.

Remember Zeta. I bet those scientists had no more desire to release undigested results prematurely than you or I would count our chickens. In my view they were pushed. Then again, because science has pull with the public, and presumably the public overseas, we recruit scientists far more readily than engineers. Last week Sir Roy Fedden drew attention to a curious anomaly: though we turn out roughly as many scientists per head of population as America and Russia; we only produce between a third or a sixth the number of engineers. It's partly because the publicists get worked up over science and can't in any case distinguish between scientists, applied scientists and engineers. After all Zeta is an engineering job.

Now I've fallen into the trap of trumpet blowing—rooting for the poor misrepresented engineer. He does all right. It's just that everybody seems to be scrambling for kudos, like small boys for pennies. We count successes as if seeking to reassure ourselves—Black Knight, Zeta, the Comet, Calder Hall, Everest conquered, the Channel swum again. Most of these are indeed fine achievements, but do we need them to bolster up our self-respect? Should we not take them in our stride? Once, our very reticence made evident the confidence we felt. Now we even have posters to convince ourselves. If " Britain's achievements speak for Britain " why do we have posters—excellent though they be—to speak on our behalf? I suppose that nowadays we have to sell ourselves. Maybe I'm just behind the times.

CAPRICORN

Weekly Survey

Era of Capital Expansion

It is a truism to say that the engineering industry has expanded considerably since the war. Nevertheless, it is interesting to put that expansion against its broad statistical background from time to time. The latest opportunity for doing so comes with the *National Income and Expenditure 1958*, published recently by HM Stationery Office (price 7*s* 6*d* net). This annual publication covers the United Kingdom national income, productivity and expenditure from 1948 to 1957, that is for a complete decade and compares the figures with 1938. Between 1948 and 1957 the national income increased from £9·5 thousand million to £17·6 thousand million and, although this represents in part a big increase in prices, it also records a large expansion in real income. Over the same period net fixed investment, which includes all forms of plant, equipment and machinery outlay, went up from 5·9 per cent to 9·2 per cent of the national income. This figure of not very far short of 10 per cent last year compares with 6·2 per cent in 1938. It is thus apparent that although the standard of living has increased notably since the war, the country has been able to put an increasing proportion of its resources into new equipment.

Gross fixed investment, which is net fixed investment plus depreciation, was 17·6 per cent of the gross national product in 1957. By using this gross figure it is possible to get a comparative figure for the first quarter of 1958. The figure for this period works out at just on 18 per cent which shows that the proportion of resources going to fixed investment in the early months of the year had not been seriously affected by the slowing down in industrial activity which has become apparent this year. The latest returns from the Board of Trade panel of companies offering to forecast their capital expenditure showed that there was a significant fall off in expected capital outlay in the winter of 1958 and the spring of 1959. If this should occur, then gross fixed investment should begin to fall off as a proportion of the national income taking the national income with it in due course. It has, however, yet to happen.

Big Jets

The first impact of mass jet transport is almost upon us. Pan American World Airways have announced the inauguration of their first transatlantic service with the Boeing 707 on 26 October between New York and Paris. Services between New York and London are planned to start on 16 November. Both routes will be run on a daily frequency. American Airlines have announced tentative schedules for a number of internal cost-to-coast flights with Boeing 707's to be started in early January 1959.

Meanwhile the Comet 4 has achieved some remarkably successful proving flights, including on 14 September the 7,925 mile Hong Kong—London journey in 16 hours 16 minutes flying time, and while the existence of a race to be first with a transatlantic service is denied by the participants, BOAC may in fact be the first between London and New York.

For many years, runways and their length and expense appeared to be major factors in the development of long-range land-based aviation. The case for the flying boat (" runways unlimited —by Nature ") was fought tirelessly by an enthusiastic band whose voices are now nearly silenced. In the end it appears that if the aircraft are built, the runways will follow (unless all runways lead to Rome). A year or two ago, many delighted in the picture of airlines with large fleets of jet-engined monsters—and nowhere to fly them from. There can now be no doubt that over many lucrative and competitive routes the giants will soon be in operation. Too much emphasis can, however, be placed on the prestige routes; a major expansion in air travel must embrace a far wider network of routes, where airport facilities cannot be expected for some years yet to approach those of, for example, London and New York.

Noise is another question. It is heartening that large sums have been spent on research into this problem, and with apparent success. It is heartening too that some loss of efficiency should be accepted in the interests of preserving such " amenities " as remain in the vicinity of airports. No relaxation should be permitted on this score. The recent noise tests at London Airport have apparently been satisfactory. " There have been some complaints from residents living near the airport, but then there always are." Such residents may of course be right; they can perhaps be too easily dismissed as diehards. There may, perhaps, be just a few too many modern Bellmen automatically repeating, for our own good of course, " What we tell you three times is true."

Link for Automation

Progress in the chemical industry in recent years has made the self-optimising plant a practicable possibility. An important component in any such plant is the equipment that continuously monitors the quality of the product or of any of the streams that carry important materials processed to form the product. Such equipment differs radically from the instruments used normally for laboratory analysis since it must produce a continuous output having a form suitable for use in data-processing systems employing computers. The delay in producing a comprehensive range of such instruments has been one of the main obstacles to automation.

Recently Elliott-Automation announced that they had entered into an agreement with Consolidated Electrodynamics Corporation, Pasadena, California, under which the Elliott-Automation Group will manufacture a wide range of analytical and control instruments of Consolidated design. The Group already have a large range of data-processing, control, and actuating equipment and see this latest agreement as an important step towards the introduction of completely automated plant. The value the Group place on the agreement is such that negotiations have been under way for eight years.

The analysis instruments that Consolidated now have available are designed for continuous operation under arduous conditions. The range includes laboratory and process chromatographs, a small mass spectrometer, a process moisture meter, a process refractometer, and a process oxygen analyser, all of which will be manufactured by the Elliott-Automation Group in their quality control instrument division. The instruments will be sold largely to the oil, chemical, coal by-products, gas and other industries.

Plant Growth

The Incorporated Plant Engineers have not the length of life of some other professional bodies in this country; in fact the Memorandum of Association was not signed until 3 September 1946. The idea originated during the Second World War as a result of meetings between those responsible for the operation of imported American equipment, particularly excavators. By the end of that year the membership had risen to 120, and the subsequent growth has been such that there are now 18 branches with a total of some 4,000 members. This growth

has encouraged the institution to move their headquarters from Solihull to London, and premises have been taken at 2 Grosvenor Gardens, S.W.1.

The institution defines a plant engineer as "... one who by virtue of the combination of his education, training and experience, is able to assume personal responsibility for the development and application of engineering science and knowledge in research, development, specification, design, construction, manufacture, management, and the education of other plant engineers"—a definition which obviously covers a wide range of people and functions. The institution has therefore framed its membership requirements so that men of much experience but modest academic qualifications need not be excluded.

Dollar Imports Freer

The announcement made by Sir David Eccles last week at the Commonwealth Economic Conference in Montreal that there would be large cuts in controls on dollar imports into the United Kingdom was more important for its timing than the substance of the cuts proposed. The categories of goods immediately affected are dollar imports of industrial equipment including agricultural and office machinery (a limited range of specialised machinery will remain restricted), canned salmon and newsprint. A relaxation of controls on consumer goods is envisaged, probably next year.

There is no control on chemicals, animal foodstuffs and basic manufacturing materials from the dollar area into this country at the present time and those wishing to import machinery are required only to show that they cannot obtain it from other sources. It is on consumer goods that restrictions are most severe. So far as industrial equipment is concerned the removal of restrictions is not likely to lead to a large increase in imports from North America. It may be a different story next year if quotas on consumer goods are increased or removed altogether.

Although the impact on United Kingdom trade of these administrative changes is small, the effect on world opinion may be considerable. It is significant, not only that the United Kingdom Government chose the Montreal Conference to make the announcement, but also that it is a curtain raiser for the annual meeting of the directors of the World Bank. This country goes to the Washington talks not only with a strengthened currency but also having made a significant gesture towards the further liberalisation of international trade.

Nato on the Clyde

According to an announcement by the United States Department of Commerce, European and American concerns are being invited to tender for the construction of a boom defence system on the Clyde which is to be completed by 1961. The project is to cost £800,000. It involves land reclamation, jetty, workshop and office buildings on the Clyde estuary. For security reasons the exact location of it is not being divulged for the time being. The work involves the construction of a jetty, land reclamation, shallow-water barricades and some railway construction.

During the last war the Clyde became the most important unloading point from across the Atlantic as the other deep-water terminals in the country became gradually affected by systematic bombing. It was also the biggest convoy organisation point. A boom defence system was run between the Dunoon and the Cloch lighthouse, a few miles south-west of Greenock. Large unloading installations were also constructed in the Gare Loch which are now mainly given over to ship dismantling and scrapping. The decision to establish Nato installations on the Clyde should certainly be welcomed locally. It is bound to bring increased work to Clydeside and it will help the Clyde to maintain its traditional position as a key point in our sea defences.

Hurry on Down

It had been expected for some time that hire-purchase controls would be cut this autumn. The strong trend towards lower interest rates and the direct challenge to the hire purchase companies by the big banks with their new credit facilities combined to make a gesture towards the hire-purchase trade imperative. The idea of stimulating the economy through consumer goods also appeals to a Government anxious to steer a middle course between inflation and deflation. It is acutely aware that if wage increases are granted at a rate of between three and four per cent per annum while the supply of consumer goods is not allowed to expand to mop up the additional purchasing power, inflation can develop, thus raising costs, weakening our export potential and causing another crisis in sterling. When the controls were removed last week, the Government announced explicitly that the defence of sterling was still the top priority.

Hire-purchase deposits have been cut over about a dozen classifications of goods and the list has clearly been drawn up with a view to furthering economic policy. The need for deposits has been removed entirely from commercial vehicles, bicycles, industrial and agricultural plant and furniture, carpets and cookers. It has been reduced from 50 per cent to 33⅓ per cent in the case of radio and television sets and a list of domestic appliances. The deposit on motor cars remains unchanged. The list has thus an industrial bias. Consumer durable goods benefit to some extent, except for motor cars, which are enjoying record sales and must not be tempted to switch from the export to the domestic market.

Keeping India Afloat

Large countries are a perpetual example of the old banking dictum that if a man wants a further advance he does better in the negotiations if he is already a large debtor than if he is a small one. Some ships are too large and important to be allowed to sink and in the present state of the world India is one of them. It is not surprising, therefore, that the Indian Finance Minister left Washington last week for the Commonwealth Conference at Montreal with an excellent prospect of getting the necessary assistance from the United States and the World Bank to complete the five-year plan.

The Finance Minister estimated in Washington last week that India needs a further 800 million dol to complete the plan. Of this 350 million dol is already assured. Adjustments have been made in the plan and India is now confident that it can obtain the rest of the money from its creditors. It puts down its financial embarrassment to the fall in export prices which has reduced its foreign currency earnings and expects its economy to have expanded sufficiently by 1961 or 1962 to be able to service new loans out of its current production of goods and services. It is to be hoped that this is so. One of the difficulties about the plan so far has been an over-optimistic forecast of the rate of increase of productivity in the Indian economy.

If export prices recover sharply in the next year or two India may well be able to get on its feet. If not, the western world has found itself a very large debtor to which the banker's dictum already referred to will undoubtedly continue to apply.

Letters to the Editor

WORLD URANIUM RESERVES

SIR, The Atomic Review article entitled "World Programme," published on page 262 of your issue of August 29, was most interesting. I should like to point out, however, that the description of the South African uranium reserves as "the largest known in the world" is in error. The facts are that Canada's reserves far exceed those of South Africa in realistic terms of pounds of uranium oxide minable. Correspondingly, Canada's current rate of production, in terms of oxide, is more than twice that of South Africa. Present officially published ore reserve figures are as follows:—

CANADA: 376 million tons at 2·25 lb U_3O_8 per ton = 846 million lb U_3O_8.

SOUTH AFRICA: 1·1 billion tons at 0·6 lb U_3O_8 per ton = 660 million lb U_3O_8.

UNITED STATES: 75 million tons at 5·4 lb U_3O_8 per ton = 405 million lb U_3O_8.

The above Canadian estimate is for "proven" and "probable" reserves; "possible" or "potential" figures are not offered but, of course, they would be considerably larger. This error in the relative positions of Canadian and South African uranium reserves is quite prevalent. Your excellent publication can do much to correct it.

Yours very truly,
FRANC. R. JOUBIN.

Franc. R. Joubin and Associates Mining Geologists Limited,
68 Yonge Street,
Toronto 1, Canada.
16 September, 1958.

Editor's Note: The statement which appeared in Atomic Review was taken directly from a recent Central Office of Information document compiled by representatives of the countries concerned. Entitled Nuclear Development and Co-operation in the Commonwealth, *the COI report includes the sentence "South African uranium reserves are the largest known in the world (excluding the Soviet bloc)."*

RAILWAY ACCIDENTS

SIR, Your leading article "Solely Responsible?" on the railway accident at Lewisham (ENGRG., 1 Aug., p. 129), and the ensuing correspondence, have used the word responsibility in several different senses. Some basic issues may be clarified by discussing this slippery concept in further detail.

A man may be irresponsible in the sense that the demands of a given situation exceed his individual capacity. The word may also convey moral condemnation, and connote certain legal liabilities. The latter meaning is appropriate when considering acts of deliberate wrong-doing such as forging a cheque, but the former is surely more relevant when considering failures of human vigilance.

The distinctions have great practical importance when considering the possible functions of courts of inquiry into railway accidents. The primary purpose of these inquiries can be to blame and condemn individuals, or they can try to establish general causes and links between whole classes of accidents, as a first stage in finding remedies. In the latter case, the emphasis would be on organisational rather than individual faults. It is extremely difficult (perhaps impossible) to combine the two functions, since full and accurate statements are not readily obtained in trials which involve basic self respect. Apart from deliberate lying, there is strong evidence that what a man perceives, learns, remembers, or forgets, is powerfully affected by his own self interest.

Your leading article contains the reasonable suggestion that the present system of inquiries (in effect, courts martial), should at least be supplemented by controlled scientific investigations whose primary purpose would be to determine underlying facts. The investigators might well include people trained in the behavioural sciences, with a tendency to exclude those trained

more specifically in military arts and practices. A first object might well be to determine whether in fact the public condemnation of individual lapses of attention does anything to improve the zeal and vigilance of others. The point has been in some dispute since Admiral Byng was shot " pour encourager les autres," yet it appears as the only rational basis for the present methods of inquiry. This question, and others of similar importance, could probably be settled by modern experimental techniques.

There are implications of irresponsibility in the sense first defined whenever an accident occurs. The traditional system of inquiries tends to emphasise those of train crews and it is fair, therefore, that your leading article and several letters (See ENGRG., 15 Aug., p. 195), should call attention to similar inadequacies in designers and management. Their responsibilities are to use the most modern techniques and data in designing signals, instruments, and controls; to select suitable operators; to train them effectively; and to test them for continued efficiency. The only real solution to such problems is that large concerns should employ their own specialists, since modern advances in the behavioural sciences should preclude non-professional dabbling.

Mr. D. R. Carling (ENGRG., 29 Aug., p. 259) points out that all machines in service cannot possibly have all the latest improvements. This is true, but it evades the real point at issue, namely, the permissable delay between scientific findings and their application, before irresponsibility is used in its second and quasi-criminal sense. There is unfortunately plenty of evidence of apathy and indifference to reliable data concerning the emotionally charged subject of human behaviour. Mr. Carling points out the need for methods of assessing whether men are fit to discharge exacting duties. But work on this and similar problems began in this country over 30 years ago, although it is still rare to find applications of the data in the land of their origin.

If we must use responsibility in its second sense and apportion blame, then it surely lies on everyone concerned, train crews, designers, management and inspecting officers, not forgetting research workers in the behavioural sciences who have somehow failed to present their work to best advantage.

Yours faithfully,

C. B. GIBBS.

75 Netherhall Way, Cambridge.
16 September, 1958.

FLYING BUSINESS MEN

SIR, I was most interested in Mr. David Brown's letter on page 363 of your issue of 19 September, and, as an executive of a firm who uses a private aircraft as a method of quick transport, I fail to understand the illogical decision of your Minister of Transport and Civil Aviation regarding the closure of Croydon Airport.

It appears that the Minister concerned suggests Gatwick as an alternative. However, the Minister does not seem to realise that up to last week there was only one runway, east-west, and that the prevailing strong winds in this region are southerly, usually from 30 to 40 knots. Does he mean to say that it is considered fit for light aircraft ? The alternative of Biggin Hill is ideal, but has the Minister decided on a suitable means of transport to the centre of London; for example, in our case, Victoria Street. On inquiring, I found that this was lacking and the time factor from Biggin Hill to Victoria Street is longer than from Paris to Biggin Hill. Does he consider this to be reasonable ?

As a Frenchman in your country, and abiding by your laws and regulations, I would not question the wisdom of your competent authorities, but I hope you will not mind my suggestion that aviation is a thing of the present and future, in business as well as pleasure, and I would have hoped to see a more realistic outlook by a responsible body in enabling a capital city to have within easy reach an aerodrome for the use of business men as well as tourists. It does not appear to me that the Ministers responsible are aware of the growth of private business and tourist aviation in France, the Continent, and the United States of America.

It would be desirable that British users of this aerodrome should petition for their rights.

Yours faithfully,

F. COUESNON,
Director.

KnitMesh Limited,
36 Victoria Street, London, S.W.1.
19 September, 1958.

MOVING PEOPLE ON

SIR, With reference to the article " Passenger Flow in Subways and on Staircases " (ENGRG., 22 Aug., '58, p. 245) certain investigations of my own may be of interest.

I noted at my local suburban station that overcrowding up the 1 in 10 exit ramp took place, and that speed, concentration and flow appeared to be sufficient to define the problem. The ramp was 156 ft long and 7 ft wide, and had roof supports at 9 ft intervals. I took as my unit the 7 ft by 9 ft cell and found that I could make a rapid appraisal of its contents at the moment the man in front reached the start of the 9 ft length, and time him with a stop watch until he had reached the next standard 9 ft away. By mingling with the crowd night after night some 313 cell measurements were obtained.

The results are shown in the attached table:—

Number in cell	No. of readings	Mean time in sec	Standard deviation in sec	Speed, m.p.h.	Concentration per sq. ft	Flow per min
1	32	2·15	0·47	2·64	0·016	26
2	24	2·14	0·32	2·65	0·033	52
3	30	2·31	0·40	2·46	0·048	73
4	24	2·35	0·41	2·41	0·063	95
5	29	2·49	0·47	2·28	0·079	112
6	23	2·66	0·51	2·13	0·095	125
7	22	3·15	1·31	1·80	0·110	124
8	13	3·69	1·11	1·54	0·127	121
9	20	4·15	0·88	1·37	0·143	121
10	10	4·80	1·43	1·18	0·159	116
11	10	6·36	2·15	0·89	0·175	96
12	9	6·42	2·07	0·88	0·191	104
13	14	6·32	2·28	0·90	0·206	115
14	17	6·97	1·52	0·81	0·212	111
15	14	7·82	1·73	0·73	0·238	108
16	10**	8·82	2·03	0·64	0·254	101
17	5*	9·04	2·87	0·65	0·270	108
18	3	9·50	1·76	0·62	0·286	110
19	1*	6·00	—	0·98	0·302	182
20	3	6·50	1·50	0·90	0·318	177

* Complete stoppage excluded from readings

The above observations, when plotted, show a family resemblance to the curves published in your article.

The lower maximum speed was no doubt due to the tiring effect of a long ramp; and to have some comparison with speed on the level, the times taken by 159 miscellaneous people passing by my front garden were measured. These would be of a mixed purposeful population of those going to a sports field, and those going to a hospital on visiting day. The mean speed was found to be 3·4 m.p.h., with standard deviation of 0·49 m.p.h. This agrees with that quoted in your article for free passenger flow.

The main conclusion from the above investigation (which was not pursued owing to change of domicile) was the odd fact that over crowding as such has little effect on flow. Broadly, the same number of people pass a given point whether they are densely crowded or somewhat sparse, and this is so up to the time when they actually stop. The second fact which may be derived from the figures is that the standard deviation rises with the mean value, which would seem to indicate that an exponential law is involved.

I have found, in general, that a better picture is given if the inverse of concentration and speed are used as variables, and the mode is sometimes more consistant than the mean. The above table differentiated by cell contents is not all statistically significant, but is as recorded. This obviously applies to the last two values. The number of readings in any cell is not significant in itself as, after a time, common values were not recorded.

I agree that simple hydraulic theory has nothing to offer apart from the beneficial advantages of stream-lining, but Professor M. J. Lighthill has apparently found an analogy in hydrodynamics (" Away with Guesswork," ENGRG., 22 Mar., '57, p. 353). A more puzzling feature is the lack of analogy with motor traffic flowing along a road where flow apparently varies markedly with alteration to density (*Road Traffic and Its Control*, by Sir Alker Tripp, E. Arnold, Ltd., London, 1950).

In my experience the most potent crowding factors are right angles of any sort, and the lack of protection to ticket collectors, which causes them to block the outlet. The fact that there is still a lot to be learned on the subject of over-crowding may be realised when it is known that the concentration in the Black Hole of Calcutta was about the same as in a well-loaded lift, namely, 0·57 persons per sq. ft.

Yours faithfully,

A. H. JENKINS.

3 Middlethorpe Drive, York.
15 September, 1958.

PAYING WAGES MONTHLY

SIR, Capricorn's suggestion might be more acceptable if linked with payment on the 15th of the month. (ENGRG., 19 Sept., '58, p. 362.) This would be more equitable than the commoner present practice of paying at the end of the month, for, in the first half of the month, the worker would be awaiting pay and, in the second half, the employer would be awaiting service.

Yours faithfully, F. H. BELL.

72 Wandsworth Road,
Heaton, Newcastle upon Tyne 6.
19 September, 1958.

SHAW'S ALPHABET

SIR, Capricorn raises several interesting and important points in the Plain Words published in your issue of 12 September (p. 330).

He is quite correct in his assertion that scientific workers would approve of an improved system of spelling, but I fear that he does the literary men less than justice since they have, for many years, used a system of phonetic notation for the recording of the exact sound produced by a speaker. This notation would seem to fulfill all the requirements of Shaw's alphabet and to have the advantage of being in operating existence at the present time.

On the other hand, it is quite untrue to think that the new alphabet would remove all our spelling difficulties. These lie at the root of our language and cannot be caused to vanish by decree. As a small example consider the words " bough " and " bow." In a phonetic alphabet these would still exhibit ambiguity.

The difficulty of the matter lies not in proposing solutions to the problem but in getting people to agree to accept them. After all, there is a much more glaring reform which should be made: the adoption of the decimal system for measurement and currency. All agree that it is desirable, all agree upon the means of solution, yet it is not introduced although the savings would probably exceed those produced by a new alphabet.

As far as machine translation of language is concerned, the position *vis-à-vis* the new alphabet is even weaker. It would have no affect whatever upon the design of translating machines, neither would it speed their operations.

As far as voice operated phonetic typewriters are concerned, the new alphabet would make their acceptance easy, but, unfortunately, it would do nothing to improve the semi-literate verbosity that most users of tape recording machines perpetrate in the name of dictation and which only disappears through the ministrations of a tactful secretary.

Yours faithfully, A. D. BOOTH.

Birkbeck College, London, W.C.1.
18 September, 1958.

Plant and Equipment

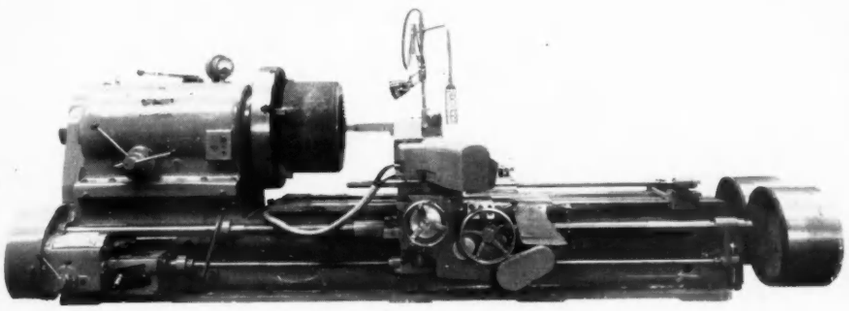
PROFILE BORING AND TURNING

Primarily intended for the profile boring of marine diesel engine piston heads, the lathe illustrated on this page will not be wholly occupied on that work, and it has accordingly been fitted with normal equipment for all standard turning operations. It has been built by Denham's Engineering Company Limited, Empire Works, Halifax, for Swan, Hunter, and Wigham Richardson Limited, Newcastle upon Tyne.

The lathe is driven through a multi-plate clutch by a 30 h.p. screen-protected reversing motor. Hardened and ground gearing provides a range of 18 speeds, from 304 to 6 r.p.m. of the ball and roller-bearing-mounted spindle. A 36 in diameter independent four-jaw chuck is fitted to the spindle. Hydraulic copying equipment, working from templates, is used for the profiling work. For normal turning the lathe is provided with a tailstock and lead screw, and will accept up to 7 ft between centres.

The carriage comprises an apron with a single lever for selecting and engaging the longitudinal and cross-traverse feeds (a range of 54 feeds from 0·002 in to 0·125 in per revolution) and a special saddle which carries either the hydraulic-copying slides or an interchangeable set of standard compound tool slides. There are four hydraulic slides: a main swivel slide, adjustable through 360° on the cross slide; the copying slide moving on the swivel slide; the auxiliary slide, which is positioned radially to establish the line of the tool slide relative to the lathe centre line, irrespective of the setting of the main swivel slide; and the tool slide itself. A No. 50 B.S. taper bore in the tool slide takes the range of special boring bars and toolholders and a hardened toolholder block for standard turning and facing tools.

Special attention has been paid to control accessibility, combined with full observation of the boring operation. It is expected that a floor-to-floor time of 12 hours will be attained for the 670 mm diameter piston head as soon as the operator has become familiar with the machine; this time compares very well with the previous one of 30 hours when hand turning to sheet metal gauges was the rule.



Specially designed for the profile boring of diesel engine piston heads, this Denham lathe is also fully equipped as a standard centre lathe.

HIGH-PRESSURE ELECTRO-PNEUMATIC VALVES

A new series of two-way electro-pneumatic aircraft stop valves, with extremely short response times, has been introduced by the Hymatic Engineering Company Limited, Redditch, Worcestershire. They have been designed for the remote control of pneumatic actuators and services, and of fuel and oxidant tank pressurisation from high-pressure bottle supplies.

The most rapid response, of 22 to 30 milliseconds, is provided by type MD34/2, while the other three valves are all in the 150 to 350 milliseconds range. Types MD34/1 and MD34/2 permit operating pressures of from 600 to 1,800 lb per sq. in; type MD30/1 of pressures ranging from 1,800 to 3,000 lb per sq. in; and type MD35/1 of pressures between 500 and 4,500 lb per sq. in.

Each of these solenoid actuated valves has a servo action. The solenoid operates two ganged pilot valves which admit high pressure gas to, or exhaust it to the atmosphere from, a chamber between two pistons. One of these pistons forms the main inlet valve and the other operates a ball-type breather valve for the downstream system through an operating pin. The solenoid assembly contains springs which prevent inadvertent operation of the valve by sudden acceleration, and which limit the loading applied to the lower valve seat by the solenoid.

In the unenergised condition, high-pressure gas is admitted through one of the pilot valves to the chamber between the two pistons. This process assists a spring in holding the main valve piston on its seat and simultaneously moves the breather piston, thereby opening the ball-type breather valve, which, in turn, vents the downstream system to the atmosphere.

When the coil is energised, the pilot valves are moved, cutting off the gas supply to the chamber between the pistons and venting the gas in it. The high-pressure gas acting on the effective outer rim area of the main valve opens it and allows a free flow of the gas. The breather valve is closed by spring action and prevents leakage from the downstream system.

Subsequent de-energising of the solenoid allows gas to be admitted to the chamber and, assisted by a spring, the inlet valve closes, the breather piston moves and the pin lifts the ball off its seat and vents the downstream system. In the MD34/2 type, the solenoid has been designed for intermittent operation only; the limit of the working temperature of the coil being reached after approximately 5 minutes of continuous energising.

AIR CONDITIONER

A weather sensitive control unit for heating systems has been developed by the Stonebridge Electrical Company Limited, 6 Queen Anne's Gate, London, S.W.1. It is designed for use with oil-fired boilers. The arrangement can be used either with two independent boilers or with a single boiler that has a two-position control for the burner.

Signals from an outdoor probe are compared with those from an indoor one and integrated to operate the boiler controls. A particular example is the case of a school which is shut down for the weekend; after the shut-down both burners are brought into use to raise the temperature rapidly, whereas in the mornings when the temperature has not fallen greatly only one is used. A time clock can also be included to switch on and off at certain times, according to a chosen programme. The control cabinets are semi-standardised.

MEASURING SMOKE DENSITY

The " Smokescope " is an instrument designed to give a quick and accurate estimation of the density of smoke issuing from a factory chimney. Made by the Mine Safety Appliances Company Limited, Queenslie Industrial Estate, Glasgow E.3, it is shown in the accompanying illustration. The single eyepiece receives light from the two objectives, one of which is clear and so gives a view of the smoke coming from the chimney, and the other of which is obscured by a disc of film of density equal to Ringelman chart 2 or 3. Thus a direct comparison is obtained with the same background of light and with the images of the chimney and the film at the same optical distance. Variations in background and ambient light, therefore, do not affect the observation and the observer does not have to alter the focus of his eyes when changing from the smoke to the chart.

The Smokescope gives a direct comparison of smoke emitted and chart density.

Continuing **Plant and Equipment**

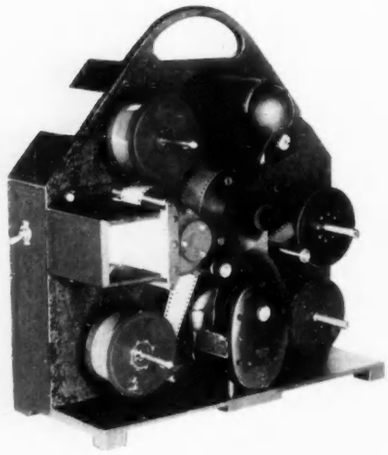
SPEED REDUCTION PULLEY

The Andantex speed reduction pulley shown in the illustration is now available in this country from Furnival and Company Limited, Reddish, Stockport. As can be seen it is of the sun-and-planet type and there is a range of sizes to transmit up to 80 h.p. One of the main features of the pulley is the method of fixing the gears to the shafts. Steel keys are not used but instead the gears are first located in position by adaptors and then liquid nylon is poured into what would have been the key-ways. This sets and is cured thus forming, virtually, nylon keys which have sufficient flexibility to allow the gears to share the load equally. The nylon keys also act as safety links as they will shear in the event of the load exceeding four or five times the rated value. A new key can be fitted in a few hours.

Various ratios are available ranging from 2·79 : 1 to 273 : 1 when the driven shaft rotates in the same direction as the drive, and from 1·79 : 1 to 272 : 1 when the rotation is reversed. Various accessory equipment can be mounted on the pulley itself (so that it forms a single unit) in order to lock one of the sun gears and so give two speeds that can be locally or remotely controlled; or to act as torque limiters or clutches. The gears run in a sealed oil bath.

Speed reduction is obtained by internal gears.

CONTINUOUS PRINTER



A portable machine for printing continuous strips of 35 or 70 mm film has been produced by Fairey Air Surveys Limited, 24 Bruton Street, London, W.1. It can be used for producing either positives, or duplicate negatives from positive stock.

As may be seen from the illustration, the film is wound on a series of drums, negative and positive meeting on a common central drum above which is mounted the printing lamp. A rheostat at the side of this controls the illumination. On the left is a negative viewer with a separate control switch which permits continuous monitoring of the negative so that any necessary corrections to the exposure can be made without stopping the machine. A safe light, orange in colour, is employed, so that the printer can be used in a darkroom with other equipment without risk of interference.

The drums will hold up to 100 ft of film, which can be processed at a constant speed of 9 ft a minute. The two feedspools, shown on the left in the illustration, are prevented from overrunning by friction discs on the spindles, while the two take-up spools on the right are driven through slipping belts to ensure a positive take up. The main drive is from the motor to the printing drum in the centre. The printing lamp is a tubular 30 watt pearl unit and the viewing lamp is 15 watt orange; both they and the motor are supplied for 230 or 110 volt a.c. inputs. The complete unit weighs 25 lb and measures 17 in by 16 in by 7 in. Changing from one film size to the other requires only a few moments.

Up to 110 ft of 35 or 70 mm film can be printed at 9 ft per minute.

TWIN STRAINERS

An improved version of their twin strainer is announced by Royles Limited, Irlam, Manchester. An example is for a 20 in bore pipe system at Shellhaven. In this design the cages are not removable but there is easy access by quick-release doors. A new feature is the motorising of the changeover valves with a flameproof control switch. Hand wheels are provided for emergency operation.

TUBE CLEANING

An adaptation of their shot and sandblasting equipment has been developed by Vacu-Blast Limited, Bath Road, Slough, for cleaning tubes and pipes of all diameters. An example of the plant was shown at the recent Chemical and Petroleum Engineering Exhibition. The Vacu-Blast machine incorporates a pressure/vacuum system for abrasive feed and recovery, and a separator for the segregation of grit, slag, and dust. For tube cleaning the tube virtually replaces the gun of the equipment and has the pressure and vacuum hoses connected to opposite ends of it. With tubes of $\frac{1}{8}$ in diameter (the smallest that can be handled) the blow-through method is employed, and the same method is applicable to tubes up to 2 in diameter. For larger tubes the nozzle can be inserted and traversed along the work surface, normally starting at the far end and withdrawing the nozzle as the tube is progressively cleaned. For larger sizes still there is an angle nozzle and a spider attachment to centre it in the bore. A more specialised item is a rotary head, which consists of two rotating blast nozzles driven by an air motor. It is mounted on a carriage which is drawn through the tube.

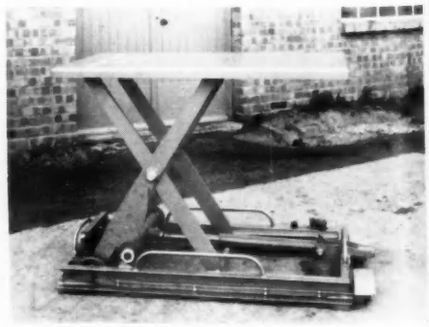
HYDRAULIC LIFTING TABLE

A transportable lifting table is among the recent additions to the Sherpa range of handling equipment made by Salisbury Engineering Limited, 1 Buckingham Palace Mansions, Buckingham Palace Road, London, S.W.1.

When collapsed, the table has a height of only 9 in so that it can easily be run under the article to be lifted. In the standard model the maximum height obtainable is 42 in and the rated load is 1 ton. The table top measures 60 in by 28 in. Power is supplied by a $\frac{1}{2}$ h.p. motor which can be for 110, 230, or 400 volts; there are foot controls for the raising and lowering operations.

Normally the table is fitted with two wheels and two feet and a detachable handle or " tug lever " for transporting it from place to place. It can also be arranged with castors or wheels of different sizes or, when wanted as a fixture, for mounting in a floor recess.

From a collapsed height of 9 in, the table can raise a load of 1 ton to 42 in.



NOTICES OF MEETINGS

Association of Supervising Electrical Engineers

LONDON
"Photo-Electric Cells and Industrial Applications," by G. A. G. Ive. North London Branch. Wood Green Hall, Wood Green, N.22. Wed., 1 Oct., 7.45 p.m.
BATH
Discussion on "The Transatlantic Telephone Cable." Bristol and West of England Branch. Royal York Hotel, Bath. Fri., 3 Oct., 8 p.m.
GLASGOW
"Lighting in Moscow," by A. G. Penny and J. F. Stanley. Glasgow Branch. Institution of Engineers and Shipbuilders in Scotland, 39 Elmbank Crescent, Glasgow, C.2. Thurs., 2 Oct., 8 p.m.

British Institute of Management

LONDON
Fourth Elbourne Memorial Lecture on "The Great Tomorrow," by the Earl of Verulam. Royal Commonwealth Society, Northumberland Avenue, W.C.2. Fri., 3 Oct., 8 p.m. (Tickets required.)

British Institution of Radio Engineers

BRISTOL
Address by Rear Admiral Sir Philip Clarke; and "The Scope and Applications of the Modern Digital Computer," by Dr. A. D. Booth. South Western Section. School of Management Studies, Unity Street, Bristol 1. Thurs., 2 Oct., 7 p.m.
CHELTENHAM
"Nuclear Instrumentation," by J. Thomas. South Midlands Section. North Gloucestershire Technical College, Cheltenham. Fri., 3 Oct., 7 p.m.
MANCHESTER
"Television Studio Techniques," by J. Chen. North Western Section. College of Technology, Sackville Street, Manchester. Thurs., 2 Oct., 6.30 p.m.

Diesel Engineers and Users Association

LONDON
Annual General Meeting. "Automatic Control of Engine-Driven Plants," by E. R. Hill. Institute of Marine Engineers, 76 Mark Lane, E.C.3. Thurs., 16 Oct., 2 p.m.

Illuminating Engineering Society

LONDON
Presidential Address on "Light and Life," by C. C. Smith. Royal Institution, 21 Albemarle Street, W.1. Tues., 14 Oct., 6 p.m.
CARDIFF
Chairman's Address by F. H. Pulvermacher. Cardiff Centre. Offices of the South Wales Electricity Board, The Hayes, Cardiff. Thurs., 2 Oct., 6 p.m.
EDINBURGH
"Lighting in Moscow," by A. G. Penny and J. F. Stanley. Edinburgh Centre. 14 South St. Andrew Street, Edinburgh. Wed., 1 Oct., 6.30 p.m.
MANCHESTER
"Lighting in Interior Decoration," by Sir Gordon Russell. Manchester Centre. Regional College of Art, All Saints, Manchester 15. Thurs., 2 Oct., 7 p.m.

Incorporated Plant Engineers

LONDON
"The Free Piston Engine and Its Applications," by R. W. S. Mitchell. London Branch. Royal Society of Arts, John Adam Street, Adelphi, W.C.2. Tues., 7 Oct., 7 p.m.*
LEEDS
"Mechanical Plant and Railway Engineering," by A. C. Layhe. West and East Yorkshire Branch. New Building, The University, Leeds. Mon., 29 Sept., 7.30 p.m.
LEICESTER
"What Management Expects of the Plant Engineer," by W. J. Worsdell. Leicester Branch. Bell Hotel, Leicester. Wed., 1 Oct., 7 p.m.
SOUTHAMPTON
Discussions: "Safety Precautions," opened by A. Simmonds; and "Preventive Maintenance," by F. V. Woods. Southern Branch. Polygon Hotel, Southampton. Thurs., 2 Oct., 7.30 p.m.

Institute of Marine Engineers and Institution of Naval Architects

PORTSMOUTH
"Recent Developments in Ship Motion Research," by E. C. Tupper. Southern Joint Branch. Portsmouth College of Technology, Portsmouth. Tues., 30 Sept., 7.30 p.m.

Institute of Marine Engineers

LONDON
"The Junior Engineer's First Trip to Sea," by H. C. Gibson. Student Lecture. Mon., 6 Oct., 6.30 p.m.*

Institute of Petroleum

LONDON
"Fuels and Lubricants for the Transantarctic Expedition," by D. L. Pratt and others. Wed., 1 Oct., 5 p.m.*

Institute of Road Transport Engineers

GLASGOW
"Oxy-Acetylene Welding Techniques," by R. Sandey. Scottish Centre. Institution of Engineers and Shipbuilders in Scotland, 39 Elmbank Crescent, Glasgow, C.2. Mon., 6 Oct., 7.30 p.m.
LIVERPOOL
"The Free Piston Gasifier, with Special Reference to Vehicle Applications," by Dr. F. J. Wallace. West Regional Centre. Offices of the Liverpool Architectural Society, Bluecoat Chambers, School Lane, Liverpool 1. Tues., 7 Oct., 7.30 p.m.

Institution of Civil Engineers

LONDON
"Engineering Problems in Recent River Valley Projects in India," by K. L. Rao. Tues., 7 Oct., 5.30 p.m.*
MANCHESTER
Chairman's Address, by J. P. Bamber. North Western Association. Engineers' Club, Albert Square, Manchester. Thurs., 2 Oct., 6.30 p.m.

Institution of Electrical Engineers

LONDON
Inaugural Address by the President, S. É. Goodall. Thurs., 9 Oct., 5.30 p.m.*
BIRMINGHAM
Annual General Meeting and Conversazione. Chairman's Address, by J. Ashmore. South Midland Centre. Grand Hotel, Birmingham. Tues., 7 Oct., 6 p.m. (Tickets required.)
EDINBURGH
Chairman's Address, by R. J. Rennie. South East Scotland Sub-Centre. Carlton Hotel, North Bridge, Edinburgh. Tues., 7 Oct., 7 p.m.
LEEDS
Chairman's Address, by J. D. Nicholson. North Midland Centre. Offices of the Yorkshire Electricity Board, Leeds. Tues., 7 Oct., 6.30 p.m.
LIVERPOOL
Chairman's Address, by J. Collins. Mersey and North Wales Centre. Royal Institution, Colquitt Street, Liverpool. Mon., 6 Oct., 6.30 p.m.
LOUGHBOROUGH
Annual General Meeting. Chairman's Address, by D. E. Lambert. East Midland Centre. Loughborough College, Loughborough. Tues., 7 Oct., 6 p.m.*
MANCHESTER
Chairman's Address, by Professor F. C. Williams. North Western Centre. Engineers' Club, Albert Square, Manchester. Tues., 7 Oct., 6.30 p.m.
PORTSMOUTH
Chairman's Address, by G. Bishop. Southern Centre. Offices of the Southern Electricity Board, 111 High Street, Portsmouth. Wed., 1 Oct., 6.30 p.m.*

Institution of Engineering Designers

NEWCASTLE UPON TYNE
"Design of Water Turbine Driven Alternating Current Generators," by G. R. Small. North East Branch. Northern Architectural Association's Hall, 6 Higham Place, Newcastle upon Tyne. Mon., 13 Oct., 7.15 p.m.

Institution of Engineers-in-Charge

LONDON
Annual General Meeting. Caxton Hall, off Victoria Street, S.W.1. Wed., 8 Oct., 6.30 p.m.

Institution of Engineers and Shipbuilders in Scotland

GLASGOW
Presidential Address, by Prof. J. Small. Tues., 7 Oct., 6.30 p.m.

Institution of Heating and Ventilating Engineers

LONDON
"Waste Heat Recovery from Diesel Engines," by R. M. Tufnell. Institution of Mechanical Engineers, 1 Birdcage Walk, St. James's Park, S.W.1. Wed., 8 Oct., 6 p.m.*
BRISTOL
"Survey of Methods of Pressurisation for Medium and High Pressure Hot Water Systems," by J. R. Kell. South Western Branch. R. W. A. School of Architecture, Bristol. Tues., 7 Oct., 6.30 p.m.
GLASGOW
"Some Aspects of Industrial Radiant Heating," by P. A. Coles. Scottish Branch. Scottish Building Centre, 425 Sauchiehall Street, Glasgow, C.2. Tues., 30 Sept., 7 p.m.
NEWCASTLE UPON TYNE
"Application of Structural Plastics in Heating and Ventilating," by R. W. Marks. North East Coast Branch. Institute of Mining and Mechanical Engineers, Neville Hall, Westgate Road, Newcastle upon Tyne. Tues., 7 Oct., 6.30 p.m.
NOTTINGHAM
Debate on the subject "That the Present and Future Revolution in Heating Technique will Lead to the Early Decease of the Heating Industry as Now Constituted." East Midland Branch. College of Arts and Crafts, Waverley Street, Nottingham. Wed., 1 Oct., 6.30 p.m.

Institution of Locomotive Engineers

LONDON
"The Mechanics of the Train in the Service of Railway Operation," by S. O. Ell. Institution of Mechanical Engineers, 1 Birdcage Walk, St. James's Park, S.W.1. Wed., 15 Oct., 5.30 p.m.*

Institution of Mechanical Engineers

LONDON
Annual General Meeting and Chairman's Address. Automobile Division. Tues., 7 Oct., 6 p.m.*
BLACKBURN
Discussion on "Atomic Energy." North Western Branch. Offices of the North Western Electricity Board, Jubilee Street, Blackburn. Wed., 8 Oct., 7 p.m.
LEICESTER
"Mechanical Properties of Plastics," by Dr. E. R. Howells. East Midlands Branch. College of Technology and Commerce, Leicester. Wed., 8 Oct., 7.15 p.m.
MIDDLESBROUGH
"Packed Glands for High Pressures: An Analysis of Fundamentals," by Professor J. L. Thompson. North Eastern Branch. Cleveland Scientific and Technical Institute, Corporation Road, Middlesbrough. Tues., 7 Oct., 6.15 p.m.
NEWCASTLE UPON TYNE
Chairman's Address, by Sir William Scott. North Eastern Branch. Neville Hall, Westgate Road, Newcastle upon Tyne. Mon., 6 Oct., 6 p.m.
RUGBY
"The Design and Development of Lightweight Marine Gas Turbines for Electric Generator Drive," by A. W. Pope. Eastern Branch. College of Technology and Arts, Rugby. Tues., 7 Oct., 6.30 p.m.

Institution of Production Engineers

LIVERPOOL
"The 1960 Associate Membership Examination and Its Implications," by F. W. Cooper. Liverpool Section. Exchange Hotel, Thithebarn Street, Liverpool 2. Wed., Oct. 8, 7.30 p.m.
READING
"Some Thoughts on the Scientific Method," by F. V. Barker. Reading Section. Great Western Hotel, Reading. Thurs., 2 Oct., 7 p.m.

Institution of Structural Engineers

LONDON
Presidential Address, by G. S. McDonald. Thurs., 2 Oct., 6 p.m.*
BRISTOL
Chairman's Address on "Modular Co-ordination in Building," by Peter Gardiner. Western Counties Branch. Engineering Laboratories, The University, Bristol. Fri., 17 Oct., 6 p.m.
GLASGOW
Chairman's Address, by W. Heigh. Scottish Branch. Institution of Engineers and Shipbuilders in Scotland, 39 Elmbank Crescent, Glasgow, C.2. Mon., 13 Oct., 7 p.m.
NEWCASTLE UPON TYNE
Chairman's Address, by D. W. Portus. Northern Counties Branch. Neville Hall, Westgate Road, Newcastle upon Tyne. Wed., 1 Oct., 6.30 p.m.

Junior Institution of Engineers

LONDON
Display of Technical Films; and paper on "The Practice and Application of Modern Air Survey Methods," by R. G. Mott. Fri., 3 Oct., 7 p.m.*
BIRMINGHAM
Annual General Meeting and Chairman's Address on "Railway Traction," by H. M. Campbell. Midland Section. James Watt Memorial Institute, Great Charles Street, Birmingham. Wed., 1 Oct., 6.30 p.m.

Liverpool Metallurgical Society

LIVERPOOL
Presidential Address on "Alternative Methods of Iron and Steel Production," by Dr. C. Bodsworth. Department of Metallurgy, The University, 146 Brownlow Hill, Liverpool 3. Thurs., 9 Oct., 7 p.m.

Physical Society

LONDON
"Vibration: Its Causes, Measurement and Reduction," by Dr. A. J. King. Acoustics Group. Physics Department, Imperial College, South Kensington, S.W.7. Fri., 10 Oct., 5.30 p.m.*

Society of Chemical Industry

LONDON
"Corrosion Embrittlement: The Effect of Cathodically-Evolved Hydrogen on Iron and Nickel," by Professor Michel Smialowski (of the Polish Academy of Sciences). Corrosion Group. Wed., 1 Oct., 6.30 p.m.

Society of Engineers

LONDON
"Bridge Over the River Kwai," by K. H. Best. Geological Society, Burlington House, Piccadilly, W.1. Mon., 6 Oct., 5.30 p.m.*

Society of Instrument Technology

LONDON
"Frequency Response Analysis Using Describing Function Method," by Professor J. C. West. Control Section. Manson House, Portland Place, W.1. Tues., 30 Sept., 6 p.m.*
BIRMINGHAM
"Instrumentation in the Oil Industry," by A. Cowan. Midland Section. Regent House, St. Phillips Place, Colmore Row, Birmingham 3. Fri., 10 Oct., 7 p.m.
CARDIFF
"Some Applications of Optics in Steelmaking Problems," by C. Burns. South Wales Section. Welsh College of Advanced Technology, Cardiff. Wed., 1 Oct., 6.45 p.m.
GRANGEMOUTH
"Data Loggers," by H. Williamson. Grangemouth Section. Leapark Hotel, Grangemouth. Thurs., 2 Oct., 7 p.m.
SHEFFIELD
"The Education and Training of Instrument Personnel," by E. B. Jones. South Yorkshire Section. The University, St. George's Square, Sheffield 1. Mon., 6 Oct., 7 p.m.

West of Scotland Iron and Steel Institute

GLASGOW
Presidential Address, by Dr. H. Harris. Fri., 17 Oct., 6.45 p.m.

The address and telephone number of the headquarters of each institution are given below. Meetings in the headquarters town are held there unless otherwise stated. Particulars for this column should reach the Editor not later than three weeks before the date of the meeting.

* An asterisk is placed where it is understood that refreshments are available prior to the time stated.

Association of Supervising Electrical Engineers, 23 Bloomsbury Square, London, W.C.1. (LANgham 5927.)
British Institute of Management, Management House, 80 Fetter Lane, London, E.C.4. (HOLborn 3456.)
British Institution of Radio Engineers, 9 Bedford Square, London, W.C.1. (MUSeum 1901.)
Diesel Engineers and Users Association, 19 Old Queen Street, London, S.W.1. (TRAfalgar 5597.)
Illuminating Engineering Society, 32 Victoria Street, London, S.W.1. (ABBey 5215.)
Incorporated Plant Engineers, 2 Grosvenor Gardens, Westminster, London, S.W.1.
Institute of Marine Engineers, Memorial Building, 76 Mark Lane, London, E.C.3. (ROYal 8493.)
Institute of Petroleum, 61 New Cavendish Street, London, W.1. (LANgham 3583.)
Institute of Road Transport Engineers, 69 Victoria Street, London, S.W.1. (ABBey 6248.)
Institution of Civil Engineers, Great George Street, London, S.W.1. (WHItehall 4577.)
Institution of Electrical Engineers, Savoy Place, Victoria Embankment, London, W.C.2. (TEMple Bar 7676.)
Institution of Engineering Designers, 38 Portland Place, London, W.1. (LANgham 8847.)
Institution of Engineers-in-Charge, 13 Grange Close, Edgware, Middlesex. (MILl Hill 3543.)
Institution of Engineers and Shipbuilders in Scotland, 39 Elmbank Crescent, Glasgow, C.2. (Central 5181.)
Institution of Heating and Ventilating Engineers, 49 Cadogan Square, London, S.W.1. (SLOane 3158.)
Institution of Locomotive Engineers, 28 Victoria Street, London, S.W.1. (ABBey 6672.)
Institution of Mechanical Engineers, 1 Birdcage Walk, St. James's Park, London, S.W.1. (WHItehall 7476.)
Institution of Naval Architects, 10 Upper Belgrave Street, London, S.W.1. (SLOane 4622.)
Institution of Production Engineers, 10 Chesterfield Street, London, W.1. (GROsvenor 5254.)
Institution of Structural Engineers, 11 Upper Belgrave Street, London, S.W.1. (SLOane 7128.)
Junior Institution of Engineers, Pepys House, 14 Rochester Row, London, S.W.1. (VICtoria 0786.)
Liverpool Metallurgical Society, Greenhithe, Grosvenor Road, St. Helens, Lancs. (St. Helens 5879.)
Physical Society, 1 Lowther Gardens, South Kensington, London, S.W.7. (KENsington 0048.)
Society of Chemical Industry, 14 Belgrave Square, London, S.W.1. (BELgrave 3681.)
Society of Engineers, 17 Victoria Street, London, S.W.1. (ABBey 7244.)
Society of Instrument Technology, 20 Queen Anne Street, London, W.1. (LANgham 4251.)
West of Scotland Iron and Steel Institute, 39 Elmbank Crescent, Glasgow, C.2. (Central 5181.)

Atomic Review

Sequence Two

A SEQUENCE of impressions gathered at the Geneva Conference may serve to show the current state of nuclear work throughout the world. Fission reactors were the subject of a first report published three weeks ago; this second series of extracts from papers presented at Geneva is concerned with fusion. In proceeding from the familiar to the less familiar we begin with a further report on British work (see ENGRG. 3 Jan. '58, p. 134); continue with excerpts from a Soviet paper discussing thermonuclear problems in general terms; and conclude with descriptions of practical approaches adopted or proposed in the United States and elsewhere. A summary of fusion work reported at the conference appeared in Atomic Review a fortnight ago, including a classification of the various approaches. The following notes serve as an introduction to the problems of thermonuclear work.

Fusion

Energy Balance

It is the purpose of controlled thermonuclear research to find an efficient way of utilising the energy produced when light elements react together to form heavier ones. Such a process occurs at the centre of the sun and in other stars under conditions of immense pressures and extreme temperatures. It is altogether impossible to reproduce similar conditions in the laboratory. Fortunately there are nuclear reactions which occur much more easily than those responsible for the sun's energy but even then extremely high temperatures are believed to be necessary.

$$ {}_1H^2 + {}_1H^2 \rightarrow ({}_2He^4) \begin{cases} \nearrow {}_2He^3 + {}_0n^1 + 3{\cdot}25\ \text{MeV} \\ \rightarrow {}_1H^3 + {}_1H^1 + 4{\cdot}03\ \text{MeV} \\ \searrow {}_1H^2 + {}_1H^2\ \text{(elastic scattering)} \end{cases} $$

Consider a cycle in which electrical energy is used to heat the gas and maintain it at a high temperature. Energy must be supplied continuously to make up the radiation loss. This energy can only be recovered as heat and some 70 per cent is lost in the conversion of this heat back to electrical energy. To make up the deficit the energy released by nuclear fusion must be at least twice the energy radiated. Both the energy radiated and the nuclear energy released can be calculated. The minimum temperature turns out to be about 3×10^7 °K for a deuterium-tritium mixture and 3×10^8 °K from pure deuterium fuel. At these temperatures the fuel nuclei have energies corresponding to about 3 keV and 30 keV. This is small compared to that attainable in modern particle accelerators. The difference lies in the much higher particle densities necessary and the requirement of confining the particles in spite of repeated collision. Not only must the hot gas be kept from the containing vessel's walls, but without adequate confinement energy will be carried away by escaping particles.

The margin between success and failure is narrow. Under the best conditions the rate at which deuterium gas produces nuclear energy is only about ten times the rate of radiation from the same gas. For a tritium-deuterium mixture the factor is a hundred and it is likely that the first successful fusion reactor will employ this fuel. At the present time the use of other fuels apart from the hydrogen isotopes appears to be excluded, firstly by the enhanced radiation due to the higher nuclear charge and secondly by the slower reaction rates. (P78, *Controlled Thermonuclear Research in the United Kingdom*, P. C. Thonemann, UK.)

Pinch Effect

Research in the United Kingdom has been devoted to a study of gas confinement by the pinch effect, that is confinement by the magnetic field which accompanies an axial flow of current through the gas. Many other possible methods have been studied at earlier times but none appeared so promising. The size of the apparatus employed depends to a large extent on the time for which the electrical current are required to pass through the gas. Thus a group at the Atomic Weapons Establishment are interested in extremely short times and a rapid increase in discharge current. MINNI, a fifth-scale working model of the AWRE apparatus MAGGI is shown in Fig. 1. The essential feature of the equipment lies in the use of a large number of separate switches (spark gaps), synchronously triggered so as to connect in a parallel arrangement the large number of condensers that form the total bank. This reduces the inductance of the circuit external to the discharge to a very low value. At the other end of the time scale is ZETA at Harwell. The discharge in the gas takes place in a toroidal vessel for longer periods of time and at much lower gas densities. Deuterium plasmas have been formed at temperatures above 10^6 °K for appreciable durations. In between these two extremes is the SCEPTRE device at the Research Laboratory of Associated Electrical Industries which is similar to ZETA but which has a more rapid rate of current rise . . .

The method of confining the plasma in apparatus such as ZETA and SCEPTRE is twofold: first, the net force acting on the gas as a whole must be zero; and second, any displacement of the gas from a position of equilibrium must lead to a restoring force. The restoring force must be produced by the interaction of electrical currents in the plasma and currents in external conductors, because forces due to particles striking the walls are to be made zero. The first condition is satisfied by the magnetic field associated with the flow of current in a cylindrical conductor and gives rise to confinement of the plasma by the pinch effect. The second condition is satisfied by enclosing the current channel in a cylindrical conductor. Any displacement of the current channel away from the axis of the cylinder results in currents in the outer conductor which, by Lenz's law, oppose the motion. . . .

The AWRE group has studied the effect of rate of current rise on discharge properties and the effect of an axial magnetic field and impurities. Studies have been concerned with the structure of hydromagnetic shock waves in a fully ionised gas and with the stability of a magnetically confined plasma. The first subject is of importance in fusion research because shock waves provide a powerful mechanism communicating energy to positive ions even when collisions are few. . . .

Fig. 1 MINNI, a fifth-scale working model of the fast-discharge straight-tube apparatus MAGGI at the Atomic Weapons Research Establishment.

In pinch-effect devices as in other approaches the confinement of plasma is not stable, and instability represents one of the major problems. Assuming the stability problems are solved, it is estimated that currents of about 10 million amperes will be required in a tritium-deuterium mixture before a net balance of power is achieved using self-magnetic confinement. In a tube of reasonable dimensions these currents must continue for at least one-tenth of a second. (P 78)

Forms of Magnetic Insulation

Methods of utilising a magnetic field for the purpose of thermonuclear insulation and heating of plasmas may be divided into two basic groups: one includes methods of accelerating the plasma by electrodynamic forces, the other methods of obtaining equilibrium plasma configurations, that is, states in which the pressure of the plasma is balanced by magnetic pressure. The two conditions are usually expressed in terms of magnetohydrodynamics, which is concerned with general laws of behaviour of a conducting fluid in a magnetic field. Macroscopically the plasma may be regarded as analogous to a conducting fluid. . . .

It is possible to imagine many ways of attaining equilibrium plasma configurations giving a quasi-stationary state of plasma in a magnetic field. At present the following trends appear to be emerging in more or less clear outline:

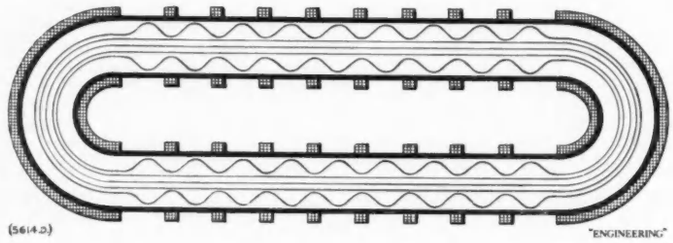


Fig 2 Magnetic-trap apparatus in which the drift of ions to the walls is restricted by means of a non-uniform winding, which causes the ions to adopt spiral paths.

(1) development of methods for confinement and heating of plasma in systems with large closed discharge currents which are maintained by an external voltage and stabilised by an external magnetic field; and (2) research into magnetic traps in which a high-temperature plasma is produced by accumulation of fast particles injected into the trap.

This classification of different approaches to the problem of obtaining and maintaining high temperatures in plasmas is of course incomplete; nevertheless, it reflects the principal trends of research on controlled thermonuclear reactions in the USSR. (P 2298, *Research into Controlled Thermonuclear Reactions in the USSR*, L. A. Artsimovich.)

Magnetic Traps

Generally speaking, the term magnetic trap can be applied to any device used to obtain ultra-high temperatures and based on the principle of magnetic confinement. However, it seems expedient to narrow its meaning to denote a more definite type of system. In pinch devices (considered above) the plasma current maintained by external sources of voltage was the main factor in confining the heated substance. External magnetic fields play the subsidiary role of combating instability. In contrast to devices of this type the term magnetic trap is applied to systems in which only external fields are employed to confine the plasma and in which plasma conduction currents do not play a decisive role. Various methods can be employed to obtain highly heated matter in magnetic traps. One possibility is to fill the magnetic system with fast ions introduced, for example, by injection from a powerful accelerator. Another way would be to fill the trap with a plasma and then heat the plasma by dynamic magnetic fields or by a high-frequency electromagnetic field. Still another possibility is that of producing fast ions inside the trap itself, for example, by accelerating ions in the plasma, which could be introduced into the trap by means of a constant or variable electric field. Magnetic traps considered so far are traps with magnetic plugs (such as the mirror machine) and traps with restricted drift (such as the stellarator). (P2298)

In the system shown in Fig. 2, which represents a form of closed magnetic trap of drift-restricting type, the magnetic field along the linear parts is corrugated (by non-uniform winding on the chamber surface). A particle moving in such a non-homogeneous field will be subjected to rotational drift and its trajectory will therefore turn about the axis of the field. Thus, despite the presence of curvilinear endpieces, after a complete circuit the particles should not approach the walls, as rotation of the trajectories in the long linear parts should balance the effect of the directed drift in the curved endpieces. (One form of the American stellarator is based on this principle; another form was described in Atomic Review on 12 September) later section. (P2298)

Confinement Time and Field Strength

If the fraction of thermal energy of a plasma converted into electrical energy in a power reactor is to be appreciable, it can be shown that the shorter the time interval during which a high temperature is maintained, the higher the magnetic-field intensity must be. In order to satisfy these requirements by means of present-day electrical facilities, the fast particles of the plasma must be confined during periods of time of the order of seconds or even tens of seconds. Thus, if the time is 10 seconds, then the field strength in a generator with pure deuterium must be of the order of 30,000 oersteds. This value is within limits technically feasible for stationary apparatus; but the power released per unit volume of the generator would be small, and for such a complex machine to be workable it would have to be of an enormous size. (P2298)

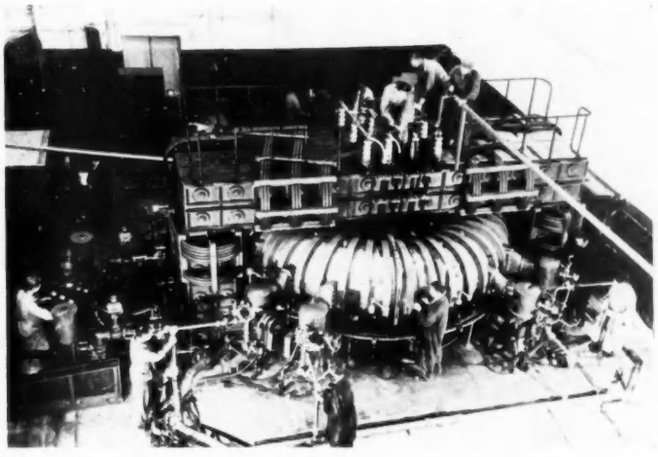


Fig. 3 ALPHA, a toroidal apparatus, similar to ZETA, in the USSR.

Direct Conversion

It may be possible to achieve direct conversion of thermonuclear energy into electric power. The energy released in a fusion reaction comprises two different parts that play quite unequal roles in the operation of a thermonuclear generator. The energy carried away by neutrons does not affect the processes occurring in a plasma. In the balance of electrical energy produced by a power reactor, this part can participate with an efficiency that does not exceed 0·3 (which equals the energy released in conventional nuclear power stations using the fission of heavy nuclei). The other part of the nuclear fusion energy is related to the charged particles produced in the high-energy reaction; it is released directly in the plasma, producing the temperature rise and it may be converted into electrical energy with an efficiency η close to unity, since $\eta = 1 - \frac{T_2}{T_1}$ and the upper temperature in the thermal cycle can be made very high.

The possibility of a transformation of this nature stems from the fact that during magnetic thermo-insulation the high-temperature nuclear fuel is surrounded by a strong magnetic field which is similar to an elastic shell compressing the plasma. Upon expansion, a plasma heated to a high temperature does work against the magnetic pressure at the expense of thermal energy, which is thus converted into electromagnetic energy . . .

The principal advantage of direct conversion is that utilisation of thermal energy of the plasma is attended by much smaller irreversible thermal losses (the magnitude of which is proportional to $1 - \eta$), moreover, the thermal conditions in the system are also more favourable since the thermal load on the plasma chamber walls is lower. The total amount of energy produced by a thermonuclear generator should not depend to any large extent on whether the thermal energy of the plasma is converted directly into electric energy or an intermediate heat-transfer agent is required. This can readily be seen if we recall that a large part of the energy released in nuclear synthesis is carried away by neutrons and cannot therefore be directly transformed into electric energy. (P2298)

Fuels

The energy yield of a mixture in equal parts of tritium and deuterium exceeds that of pure deuterium by two orders of magnitude. Tritium may be bred from a jacket of lithium 6 placed round a thermonuclear reactor by means of the emitted neutrons. (P2298)

Explosive Fast Discharges

In considering the promotion of thermonuclear reactions by means of powerful fast discharges, everything depends ultimately on two basic characteristics of the pulsed discharge: first, on the degree of compression of the plasma column which is characterised by the minimum value of the column radius r; and second, on the duration of the compressed state t. It is easy to see that the energy efficiency of a powerful pulsed discharge viewed as a source of thermonuclear reactions is proportional to the square of the current and to the quantity t/r^2. Even with optimum values it is found that the efficiency of a thermonuclear reactor based on pulsed discharges can approach unity only if an enormous amount of energy is concentrated in the system (of the order of 10^{10} Joules when operating on a D-T mixture. This energy is initially stored in the power sources and then for a brief moment of time it is converted, to a large extent, into the thermal and mechanical energy of the expanding plasma column. This stage of the process would be in the nature of a powerful explosion (an underestimate is that this explosion would be equivalent to that of 10 tons of TNT). At the present level of technical development, no way is known of utilising

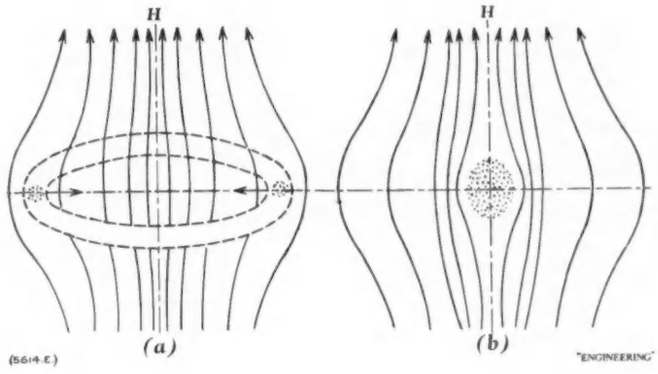


Fig. 4 Basis of plasma loop device.

Continuing **Atomic Review**

this explosive energy, and there is no means of protecting the unwieldy and expensive apparatus from the destruction that would occur after each pulse. (P2298)

Eastern Approaches

Studies of powerful fast discharges in the Soviet Union have been carried out mainly in the Institute of Atomic Energy. Certain other types of pulsed processes in which the plasma is acted on by strong magnetic fields have been the subject of investigations carried out at the physics department of Moscow University. ALPHA, a Soviet toroidal device, is illustrated in Fig. 3.

Other approaches include plasma acceleration by electro-dynamic forces, which is achieved in devices such as the electro-dynamic gun. The simple principle underlying all such apparatus is as follows. A plasmoid produced by the passage of a large current through a fine wire or gas is accelerated along metallic rails under the action of a force due to interaction of the current with the magnetic field of the lead-in feeders (or, in another version, with the external magnetic field). Experiments have shown that in systems of this type, plasma velocities up to 5×10^7 cm per sec can be attained without special effort.

Another method of obtaining plasmoids has been investigated at the Institute of Atomic Energy. First a circular plasma loop containing a current is formed in an alternating external magnetic field, the lines of force of which are normal to the plane of the loop as indicated in Fig. 4. The loop is created as the result of breakdown of the gas by the exciting electric field during build-up of the magnetic field. After a certain interval of time following the formation of the loop, the latter begins to contract rapidly to the axis and changes into a plasmoid. An outcome of these experiments may be a method of injecting hot plasmas into magnetic traps.

A pulsed thermonuclear reaction may also be possible under conditions when a high temperature is reached during the compression and cumulation produced by a charge of conventional explosives (such as TNT or something more powerful) surrounding an ampoule containing deuterium or a deuterium-tritium mixture. Neutron pulses from both types of reaction have been recorded remotely. The chief difference between this process and those involving electromagnetic compression is that it proceeds in conditions where the density of the substance is very great, considerably exceeding that of solids. Heating is so brief that magnetic insulation is unnecessary. These experiments have been discontinued.) (P 2298)

Western Approaches

United States approaches to thermonuclear work were summarised in Atomic Review last week. The following notes provide further details of certain of the systems that have been adopted.

Promising Device

"Conditions of slow current build-up for pulsed discharges in a toroidal chamber were investigated in detail by English physicists working with ZETA. Theoretically this approach seems to be the most promising as far as stabilisation of the shape and size of the plasma column is concerned."—Academician L. A. Artsimovich (P 2298).

Stellarator

A plasma may be considered from the point of view of the individual charged particles in a fixed field. The first and simplest question is whether or not a field of magnetic lines can retain ions in their orbits for a sufficiently long time. Since the ions slowly drift in a direction perpendicular to the magnetic lines of force and to the gradient of these magnetic lines, it is not clear that an effective confinement is actually possible. In a simple torus with longitudinal magnetic field, the charged particles spiral around closed magnetic lines of force. The inhomogeneity of the field causes them to wander off steadily to the walls. In the stellarator the lines are twisted either by means of additional fields or by twisting the vessel itself into a figure eight as illustrated in Atomic Review on 12 September, with the result that a line no longer closes but instead returns after a circuit, into the neighbourhood of its starting point.

If a great many circuits are executed, a single magnetic line will have closely covered a toroidal surface. An ionised particle in following this more complicated line of force will be subject to displacements due to the inhomogeneity of the magnetic field. It can be shown, however, that these displacements average zero with close approximation. (P2410, *Peaceful Uses of Fusion*, Edward Teller, USA.)

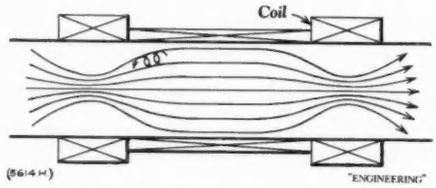
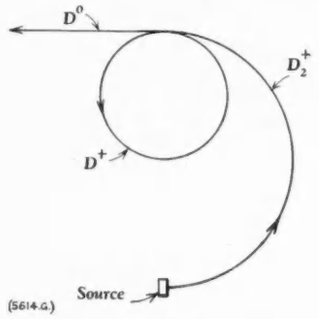


Fig. 5 Field configuration and arrangement of mirror machine.



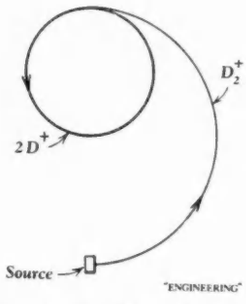
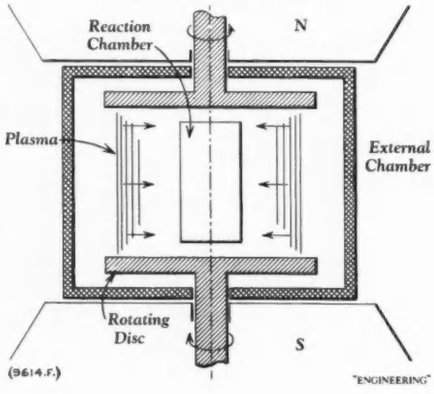


Fig. 6 Trapping of energetic deuterons in a magnetic field by dissociation of deuterium molecular ions, as in the DCX machine.

Fig. 7 Homopolar device comprising two rotating discs for creating pinch fields



Mirror Machine

The magnetic mirror effect arises whenever a charged particle moves into a region of magnetic field where the strength of the field increases in a direction parallel to the local direction of the field lines, that is, wherever the lines of force converge toward each other. Such regions of converging field lines tend to reflect charged particles, that is, they are magnetic mirrors. The basic confinement geometry of the mirror machine is formed by a cage of magnetic field lines lying between two mirrors, so that configuration of magnetic lines resembles a two-ended wine bottle, with the ends of the bottle defining the mirror regions. This is illustrated in Fig. 5, which also shows schematically the location of the external coils which produce the confining fields. The central, uniform field region can in principle be of arbitrary length, as dictated by experimental convenience or other considerations. For various reasons, it has been found highly desirable to maintain axial symmetry in the fields, although the general principle of particle confinement by mirrors does not require this in order to be operative. (P377 *Summary of UCRL Pyrotron—Mirror Machine—Program*, R. F. Post, USA.)

Direct Current Experiment

In February, 1955, observation was made at ORNL that energetic deuterons could be trapped in a magnetic field by the injection and dissociation of deuterium molecular ions, as indicated in Fig. 6. This discovery made it possible to inject pre-accelerated (or pre-heated) ions (or plasma) into some other thermonuclear machine without their immediate escape due to the continuation of their motion.

The essential feature of this method is the injection of a D_2^+ ion across a magnetic field and the subsequent dissociation of this ion into a D^+ ion and a D^0 atom or into two D^+ ions and an electron. In either case each resulting deuteron has half the momentum of the original molecule and hence half the Larmor radius in the magnetic field. If dissociation occurs at the proper point of the molecular ion orbit the resultant D^+ is trapped and does not return to strike the injector. It was reasoned and later borne out by calculations that if a sufficient number of high-energy deuterons (injection energies between 20 to 600 keV were considered) could be trapped, a thermonuclear plasma might be formed that would maintain a high temperature and could be fed by much less energetic fuel. Much of the effort since then has been directed toward the development and exploitation of devices to produce intense beams of molecular ions and to dissociate these ions with high efficiency. Both of these objectives have been achieved.

The discovery which, more than any other, made the high-energy molecular ion injection and trapping scheme appear feasible was that of a high-current d.c. arc which was found to have a remarkably high efficiency for dissociating molecular ions. This arc is run between two graphite electrodes in a magnetic field of several kilogauss and is supported by carbon from the electrodes with no supplementary gas input. Thus if an arc is established along the axis of a mirror machine, energetic deuterons (from an accelerator say) may be injected without promptly flying out again, since on meeting the arc and dissociating they will assume the motion represented by the smaller circle in Fig. 6. (P1790, *Studies of Intense Gas Discharges*, J. S. Luce, USA.)

Shock Waves for Preheating

In order to use externally generated magnetic fields to compress a high-density deuterium plasma (10^{16} to 10^{18} ions per cub. cm) with a ratio of the external magnetic pressure to the gas pressure near unity, preheating is necessary to establish a high conductivity initially. The utilisation of magnetically driven shock waves for preheating has been under investigation in

one phase of the controlled fusion research at the Naval Research Laboratory. The magnetic compression of the shocked plasma is accomplished by discharging a large condenser bank into a coil system surrounding the shock tube. With this general arrangement axial magnetic fields of the order 100,000 to 500,000 gauss can be generated with currents of $1{\cdot}5 \times 10^6$ to 8×10^6 amperes. The high magnetic pressure raises the gas to high temperatures and high energy radiation has been observed with a scintillation counter for time intervals of the order of 10 microsec.

A deuterium plasma can be accelerated along a quartz tube by striking a high current discharge, (100,000 to 300,000 amps in 0·3 to 0·5 microsec) between a pair of electrodes at one or both ends of a quartz tube. A magnetic field perpendicular to both the current path and the axis of the tube causes the acceleration and resultant shock wave. To prevent cooling by heat conduction to the tube walls a magnetic field along the tube is used to drive the plasma radially away from the walls. (P34, *Magnetic Compression of Shock Preheated Deuterium*, A. C. Kolb, USA.)

Homopolar Generation of Pinch Field

Strong magnetic fields for pinch-effect devices are normally obtained by discharging condensers into field windings, as in ZETA. An alternative method makes use of the homopolar principle. In a static magnetic field, two oppositely rotating discs are placed face to face. They are made of conducting material and have radial cuts to avoid one-turn short-circuit in the azimuthal direction. The axes of the rotating discs are connected electrically to the external chamber, which is filled with low-pressure gas. Each disc acts as a rotor of a homopolar generator and gas discharge may start between edges of the discs. The hollow column of the plasma will be pinched, so that the inside magnetic field being in pressure balance with the outside magnetic field produced by the discharge current will increase rapidly. A discharge tube may be placed near the central region as shown schematically in Fig. 7.

The plasma column in this system will not show any instabilities, it is claimed. A high temperature and the long period required for achieving thermonuclear reactions may be reached with a power supply of a large capacity. Preliminary experiments are in progress. (P1329 *Proposed Methods of Obtaining Stable Plasma*, G. Miyamoto *et al*, Japan.)

Notes and News

Fusion Work to Move to Winfrith

The United Kingdom Atomic Energy Authority have announced that they propose to move the whole of the controlled thermonuclear project from Harwell to Winfrith Heath. This work will be transferred from Harwell to Dorset during the period 1961 to 1963. The change will permit the development of both fission and fusion work at Winfrith, and allow room for whatever expansion of the latter is necessary in the future. It will also provide a margin for new work as yet unseen which will undoubtedly be developed at Harwell.

Pressure Vessel for AGR

As reported in Atomic Review on 28 March and 29 August, the UKAEA is to proceed with an advanced type of gas-cooled graphite-moderated reactor. Whessoe are to be awarded the contract for the supply and construction of the reactor pressure vessel. This advanced plant will operate at considerably higher temperatures than those employed on nuclear power stations currently under construction. A sectioned perspective drawing of the AGR was published on page 373 last week.

The AGR pressure vessel, containing the core and moderator, is a vertical cylinder of approximately 21 ft diameter with hemispherical top and bottom ends. Its overall height is 53 ft 6 in and it is to be constructed from notch ductile steel plate of considerable thickness. The top head is perforated by a large number of closely pitched charge-tube and control-rod standpipes for refuelling and controlling the reactor. The internal parts are most complex. They include the support of the heavy core and graphite moderator and the shielding material. The internal baffles are arranged in such a manner that the relatively cool inlet gas sweeps the entire pressure-vessel shell. The hot gas is collected from the reactor channels and passes out of the reactor through an inner concentric duct. This arrangement prevents the gas being in contact at any point with the vessel shell.

This nuclear reactor vessel will be the twelfth to be built by Whessoe, whose first contract for a reactor pressure vessel was secured in 1953. The eleventh is the 66 ft spherical vessel to be built at Latina, south of Rome, for the power station contract recently secured by the Nuclear Power Plant Company of which Whessoe Limited are a member company. In addition to reactor vessels for nuclear energy, Whessoe have built a number of "sealed buildings" for research reactors and have secured several design contracts for similar containment shells for Australia, India, Germany and elsewhere.

Crucial Particle Experiment

The 600 MeV synchro-cyclotron of the European Organisation for Nuclear Research (CERN) has made its first major contribution to nuclear physics. The two high-energy machines at CERN, one of which is still under construction, have been built specifically to study the properties and interactions of so-called elementary particles. One of these particles, the π-meson, was discovered in cosmic radiation, about 11 years ago. It was observed then that it decayed, in a very short time (about 10^{-8} seconds), into a μ-meson. The μ-meson itself decays in a rather longer time (about 10^{-6} seconds) into an electron. Not long after the discovery of the π-meson, it was predicted, on very simple and straightforward theoretical grounds, that every so often the π-meson should decay, not into a μ-meson but directly into an electron, and that this should occur once in every ten thousand decays (1 in 10^4). Experiments were performed at the Universities of Columbia and Chicago to look for these rare decays with the result that the process was not observed, and that if it occurred at all, it must be less than one in one hundred thousand (1 in 10^5).

The discovery, two years ago, that parity was not conserved in certain processes in nuclear physics, produced a very great simplification in the understanding of these phenomena. But there were still one or two major difficulties left, and one of the most serious of these was the negative result concerning the electron decay of the pion. This inspired several groups of physicists throughout the world to search once more for the process, and one of these groups, at CERN, has been successful. They have demonstrated that this decay does occur, possibly with about the expected frequency. The discovery has eliminated a crucial difficulty for the theorists.

Fundamental Research

In his survey of the Geneva conference, the bulk of which was published in ENGINEERING last week, Sir John Cockcroft referred to work on fundamental research. New giant accelerators had been described, and cosmic ray workers flying large stacks of photographic emulsions in Comet proving trials had been able to obtain an enormous amount of new data on the collision of protons ten thousand times more energetic than any which can be produced by the largest planned accelerators. It was also reported that orbiting satellites had revealed intense belts of 40 MeV protons, a thousand kilometres or so above the earth in particular latitudes. The great question of why pions and nucleons exist, with their particular masses and particular interactions, remained totally unanswered, in spite of the wealth of new knowledge produced by the accelerators. Strange particles had accumulated, and now totalled 31. The theoreticians had a fresh occupation of inventing new rules and waiting to see whether the latest strange particle obeyed them. Dr. Feynman had predicted that 20 years hence our successors might be convening a conference on the Peaceful Uses of Strange Particles.

Reactor technology required much more precise information. To help in this, important new tools providing enormously powerful pulses of neutrons were becoming available.

In the chemical sessions had been reported the isolation of weighable amounts of Berkelium, and chemists looked forward to going well beyond element 102, aided by expensive reactors with neutron fluxes up to 10^{16} per sq. cm per second. The chemical effects of fission fragments appeared to be much higher than anticipated, and this might have important technological consequences. There had been a rapid advance in solvent extraction technology and long chain amines and long chain derivatives of phosphoric acid had been synthesised with highly specific activities.

Fundamental Nuclear Physics Course

A course in nuclear physics intended for engineers, physicists and industrial executives, with special reference to power generation, is to be held at the College of Technology, Cabot House, Ashley Down, Bristol 7, on Friday evening and Saturday, 10 and 11 October this year. The fee for the course is £1 1*s* and inquiries should be made to Dr. H. J. Willaways.

Triton Launched and Prototype Critical

Last month Triton, said to be world's largest submarine, was launched at Groton, Connecticut, from the yards of the General Dynamics Corporation. She is the eighth of the United States' authorised fleet of 33 nuclear submarines and is powered by two reactor propulsion units. Designed as a mobile radar station to spend more time on the surface than is usual, she is 447 ft in length, has a displacement of 5,900 tons and is to have a speed approaching 30 knots.

The land prototype of the advanced nuclear reactor to be installed in the US Triton, also became critical for the first time last month. The prototype is located at the Commission's West Milton Site near Schenectady, New York. The reactor is identical to the two reactors now being fabricated for the Triton.

Elliptic Heat Exchanger Tubing

A finned heat-exchanger tube of elliptic section has been designed by TI Nuclear Engineering Limited to reduce the pressure in the gas side of heat exchangers for nuclear power stations.

NPPC Appointment

The Nuclear Power Plant Company Limited, Booths Hall, Knutsford, Cheshire, announce the appointment of Mr. R. D. Vaughan to the board of directors. Mr. Vaughan has been chief engineer of the company for the last three and a half years.

Year Book

Reference information of a most comprehensive character is provided by the second edition of the *Nuclear Power Year Book* (1958-59), published by Rowse Muir Publications Limited, 3 Percy Street, London, W.1. Among its contents are revised isotope tables, a list of world and national authorities, an extensive range of technical data, a buyers' guide and a Who's Who section. Introduced by Sir Christopher Hinton, the book is simply and systematically laid out, and a number of leading authorities have contributed to its preparation.

Own Medicine

Two exit signs lit by krypton 85 lamps have been installed in Cockcroft Hall at the Atomic Energy Research Establishment, Harwell, by Isotope Division. Each sign is made of Perspex with recessed letters coated with zinc sulphide phosphor and activated by krypton 85 gas. The intensity of light emission is expected to fall as the krypton 85 decays (half-life just under 10 years). This is believed to be the first public use of krypton 85 lamps in this country.

Companies in the News

Dowty Certain

The success of the Dowty Group continues unabated. Trading profits which in 1951 were £417,000, topped the £2 million mark for the year ended 31 March, compared with £1·7 million for 1956/57. Sir George Dowty's review of the year's activities is a fascinating account of the group's industrial product policy. The year was a record one for both turnover and profits, and Sir George expressed complete confidence in the future of the business. Although he pointed out that their interests were " now so widespread " that it would be " too much to expect each of them to have an uninterrupted growth." Progress will be overall, and the long-term prospects will depend on a continuation of the influx of new ideas and new products.

Taking each division in turn, Sir George—who was elected vice-president of the Society of British Aircraft Constructors earlier this year—reported very high output in the field of aircraft components. Landing gear, hydraulic components and fuel systems are supplied for a number of military aircraft, including the Blackburn NA 39. The division have recently obtained a production and development contract for undercarriages for the Armstrong Whitworth Freightercoach and are taking their full share of the civil aircraft business. In the guided-missile field they are making a range of electro-hydraulic control units and have taken a licence from Moog Valve of New York, for the manufacture of their servo-valves.

The mining division, now a separate company —Dowty Mining Developments Limited—are continuing their research and pioneering of new products, certain of which " show great promise." Sir George Dowty considers that there exist " good prospects for improved mechanisation of the mines," and the group are making efforts to enter the Canadian mining industry. Industrial hydraulics are being developed further, particularly in the railway rolling stock field. A new testing site for research and experimental work has been put down and a new factory has been completed at Ashchurch " to take care of future expansion." Dowty Nucleonics are engaged on new designs of equipment for reactors, with particular emphasis on trouble detecting and locating equipment. Referring to the Windscale mishap, Sir George commented that technical advances now make it impossible for dangerous radioactive materials to escape to the outer air. " Action can be taken before any significant damage can be done." Sir George also suggested that Britain needs a central public relations organ for handling nuclear publicity.

No Cable Merger

The boards of directors of W. T. Henley's Telegraph Works Company and of Johnson and Phillips have announced that the talks which have been taking place to consider a possible merger between the two companies have been discontinued. No agreement has been reached and what might have been the first major step in the concentration of the British cable industry has not been made. The problem of surplus capacity remains and other moves towards mergers can therefore be expected over the next few months.

A factor in the failure of the two companies to reach agreement may have been the turn for the better which appears to have taken place in the demand for electric wire and cable. In his annual statement to shareholders, Mr. James Clark, chairman and managing director of Sterling Cable Company, said that the company's order book was " highly satisfactory." Among the large orders he mentioned were for Dorman Long's new Lackenby Steel Mill, two large power stations for the Central Electricity Generating Board, two oil refineries in Canada, the St. Lawrence Seaway, a gas injection plant in Saudi Arabia and Gatwick Airport. Sterling made and sold more cable in the year ended 31 March than in the previous year but profit margins were less and trading profits remained about the same. The lower sales value, said Mr. Clark, reflected " the decline in raw-material prices and the intense competition now raging in our industry." This competition is general in the Western hemisphere and some degree of concentration would seem unavoidable.

Test Case

A company with accumulated capital is faced with the problem of employing it usefully. This is as true of intellectual capital as it is of the more tangible forms such as machinery and tools. Yet there are many firms with a considerable staff of skilled engineers whose accumulated experience is not, at first sight, easily convertible into commercial value; firms, for example, whose contracts have been largely made up of government orders for aircraft or guided weapons. For them, the solution to the problem is often found by entry into fields of manufacture with which they have not been previously associated. Several aircraft companies have taken up this policy; recently they were joined by another.

De Havilland Propellers Limited, Hatfield, are producing a cable test set. Although instruments have been supplied to order on previous occasions, this is the first the company have offered on the open market. It was originally produced to enable rapid checking of multi-core cables in aircraft electrical installations but is of value in any type of installation with cable runs in confined spaces. Among the industries in which applications are foreseen are shipping, railways, data processing, and automobile production. The instrument is connected into the cable by an adaptor and a test is initiated by pushing a button: each of up to 25 wires is then automatically selected in turn and tested for continuity or insulation. The company point out that the instrument thus provides in an easily portable form the facilities hitherto only available in fixed or cumbersome equipment. In fact, the portable version of the test set weighs only 19 lb.

Promoting Indian Small-Scale Industry

Assistance to small-scale industry has become one of the cardinal points of Indian policy and a considerable programme of development is being carried out. The problems of small-scale industry were the subject of a detailed study by an international team (sponsored by the Ford Foundation) whose recommendations were accepted by the Indian Government. Basically, these were the provision of (*a*) technical know-how, (*b*) credit facilities, and (*c*) marketing assistance. Early in 1955 the National Small Industries Corporation was set up as a private limited company primarily for helping small manufacturing units to market their products more effectively. The corporation, who have a capital of Rs5 million, have taken on several additional functions, such as the supply of machinery to small-scale units under hire-purchase terms, the construction and management of two large industrial estates, and the setting up of two " prototype production-cum-training centres." Four subsidiary corporations have been set up on a regional basis, one each in the Eastern, Western, Northern and Southern regions.

A review of the corporation's activities, by their managing director, Mr. A. S. E. Iyer, is published in *India News* (23 August). One of the major steps taken has been to secure the participation of small-scale industry in the Central Government Stores purchase programme. This has led to an increase in the value of contracts received by small-scale units from the Central Government (through the Director General, Supply and Disposal) from Rs467,750 in 1955-56 to Rs6,214,965 in 1957-58. Another step was to forge bonds between small-scale industry and large units. Schemes were put in hand to set up eight small-scale industries. Four will be located in the Kalyani industrial estate in West Bengal and will serve as feeders of components to Sen Raleigh Industries of India Limited. Another will be located in Bombay for the supply of components to Premier Automobiles Limited, and the remaining three at Bangalor for the supply of components and parts to Hindustan Machine Tools Private Limited. Prices at which their products will be purchased will be determined " to leave the small units a reasonable margin of profit after meeting their expenses." In many ways this is very similar to the sub-contracting system set up by the war-time British Government for the aircraft, machine tools and other strategic industries.

Working capital will be provided by the State Bank of India through their local branches on the recommendation of the Corporation, " against pledge of raw materials required for the execution of contracts." Sales are being promoted in several ways—by mobile vans operating in the major markets by the establishment of wholesale depots with an advisory service. These will promote standardisation and the use of trade names and will establish inspection arrangements to check quality. This effort to help small-scale industry is a major one—it involves huge expenditure and a completely new outlook. Whatever progress is being made by large-scale industrialisation small-scale industry remains India's industrial lifeline.

Refining in Kuwait

The inauguration of the Mina al Ahmadi refinery is the subject of a special publication by the Kuwait Oil Company Limited, which contains a full description of the refinery and a resumé of the oil industry's progress in the state of Kuwait. The refinery has a capacity of some 190,000 barrels a day and is one of the largest of its type in the world. The new plant includes two atmospheric crude-oil distillation units (each of 80,000 barrels a day capacity) and each with a gasoline stabiliser. Sixteen tanks have been built with storage capacity for 2½ million barrels of crude oil and products with all necessary interconnecting lines, pumps, and oil blending installations. Existing oil-loading facilities to the pier and submarine berths have been extended and two turbo-generators totalling 15 MW have been installed, together with additional steam generating and sea-water supply facilities, an oil-water separating plant and the necessary utility services.

The main purpose of the refinery expansion project was to meet the needs of the tankers bunkering in Kuwait which have multiplied as crude oil exports have risen. Last year 2,567 tankers were loaded with 55 million tons, and further increases are expected. Planning began in the second half of 1955, when a contract was made between Kuwait Oil Company and the Kuwait Bechtel Corporation for the engineering design of services to complete the refinery and all related ancillary facilities. Bechtel International Corporation and George Wimpey and Company supervised the engineering design of the refinery ancillaries and the procurement of materials. The design of the power plant extension was entrusted to the Bechtel Corporation of San Francisco and that of the two distillation units to E. B. Badger and Sons Limited. Kuwait enterprises were involved in a major way at the contracting end (under the supervision of Kuwait Bechtel). Most of the plant was purchased in the United Kingdom, the turbo-generators in the United States and the main distillation tower shells, some receiver tanks and pumps, coolers for residue steam, and other items from Italy.

The Human Element

Caring for Railway Travellers

Consumers' consultative committees are usually regarded as having only nuisance value, their existence being brought about by Government draughtsmen writing nationalisation Bills with their tongues in their cheeks. Care is usually taken to see that the committees are not fitted with teeth to bite at the men who have to get on with the job.

Last week they had one brief hour of glorious publicity thanks to a campaign in certain papers about the attitude of railway porters. The Central Transport Consultative Committee for Great Britain (a somewhat ponderous name which has no direct relation to the weight of its influence) discussed the matter and agreed to have a statement issued to station masters reminding porters about their obligation to help passengers with their luggage. To remind all concerned who are the real arbiters in these matters, the NUR also issued a statement suggesting that porters lounge around only in their spare time.

By a stroke of irony the committee also took users of sleeper berths to task (and rightly so) for booking sleeper berths and not taking them up. Deposits at the time of booking are to be introduced on the Scottish runs. It is a step probably long overdue. Nevertheless, it is food for thought that an organisation created to protect the customers has to set about protecting them from one another.

Safe Working

Last year saw the lowest number of accidents recorded in factories for twenty years. In his annual report for 1957 the Chief Inspector of Factories remarks that this has occurred in a year when there was an overall increase in industrial activity. Particularly gratifying to him has been the fall in the accident rate in the building industry.

This latest report has what amounts to a new format. From now on the report is reduced to about one-quarter of its old size in order to speed up publication (a long-standing source of criticism), to reduce cost and to cut down the work of inspectors in providing material. In future, sections will appear on special subjects of wide interest.

One of the issues raised this year is the danger of work involving the use of radioactive isotopes. At the end of last year some 400 factories were using radioactive isotopes and over 100 were using X-ray apparatus. Use of such equipment is expanding rapidly however. About 85 per cent of the factories concerned are using sealed sources of radiation and 15 per cent open sources. Of this 15 per cent, one-tenth are engaged in luminising with radioactive compounds. Luminising factories are covered by special regulations but there are none for factories using sealed sources. Reference is also made in the report to such engineering developments as dust control in foundries, the special problems to be found in nuclear power stations and the use of special steels in lifting appliances.

Autumn Migrants

June and September are by tradition the months when young aspirations take wings or flutter to earth. The examination results come out. One of the results of the great growth of technical education is that the autumn air is going to become even thicker with cries of scholastic triumph and disappointment.

Last week the General Electric Company Limited learned that 34 of its apprentices had become the country's first " Dip-Tech " graduates and so a new piece of educational jargon became established. This group were from a sandwich course and the results are encouraging. Of 40 students, 28 reached honours level and only 5 failed. The examination was held at Birmingham College of Technology and in making the announcement of the results the National Council for Technical Awards expressed satisfaction with the results. The course was prepared by the College in 1954 on the initiative of GEC.

Another aspect of autumn activity is the flow of literature on engineering courses open to students. In particular, there is the continued growth in the number of post-graduate courses available in specialised subjects. Meanwhile, a new pamphlet has been issued by the Ministry of Education called *Britain's Future and Technical Education*, describing the pattern being followed in the development of technical colleges in England and Wales and showing how industry and commerce can help in the scheme.

Thousand Scholarships

Ambitious proposals were announced last week at the Commonwealth Conference in Montreal for many more Commonwealth scholarships and technical training facilities. The initiative came from Canada but the United Kingdom also made proposals on its own initiative. The significance of the news is that this subject should have been raised at all and so prominently at a Commonwealth conference which by tradition is not given to making concrete proposals for technical training. Yet the Commonwealth's record on this subject is an excellent one so far as quality is concerned, the outstanding example (though rarely bestowed upon would-be engineers) being the Rhodes scholarships.

Mr. Diefenbaker for Canada proposed that 1,000 Commonwealth scholarships should be established on a reciprocal basis covering both student and teaching facilities. Lord Home for this country said that the United Kingdom would be prepared to take half the total. There is therefore a considerable impetus developing behind the idea.

The idea is that a joint study group should be formed and that there should be a Commonwealth education conference held as soon as possible, perhaps next year, to go into the matter further. The study group envisaged would include officials and education authorities from all countries in the Commonwealth.

Dons at Dijon

There have been a number of signs of recent years that the new spirit of co-operation in matters political and economic in Western Europe is beginning to bite rather deeper. It is getting below the level of *ad hoc* committees at ministerial and administrative level. This is all to the good for it means that inquiry is progressing down into the social fabric which is Western Europe.

Another manifestation of this spirit is the second conference of university rectors and vice-chancellors to be held at Dijon in France in September next year. Working parties have already been set up to prepare the ground. It will be a successor to the conference held at Cambridge in 1955 which has already become something of a landmark in the history of the co-operation of universities in Europe.

Another significant point for the Dijon meeting is the choice of themes. There are to be two. The first is " The Universities and the Shortage of Scientists and Technologists." The second is " Studies Relating to Europe in the Universities." The conference will therefore have a pronounced bias not only towards the unity of Western Europe, but also towards technical education. Both topics would have had an odd ring about them even twenty years ago.

Pit Props

Somewhat against the run of expectations, the National Union of Mineworkers last week decided to recommend acceptance of the Coal Board's offer of 7*s* 6*d* for day workers. Two conditions were attached to the offer. There should be nine months' suspension of claims for piece workers. Secondly, there should be a resumption of Saturday working at selected pits. The increase in the wage bill will presumably have to come out of the profits earned at the efficient pits now having the extra shift.

The miners' executive have still to get agreement through the delegates at area level and there is likely to be some stiff opposition. Nevertheless, the executive have a habit of getting their own way, the only big issue recently where this has not been so being the employment of foreign labour. On this occasion the union is accepting two rather important matters of principle which will not be easy for many of the rank and file to stomach. It is accepting discrimination among its members both on wage claims and on opportunity to earn overtime rates—which is what the Saturday morning shift amounts to.

Medical Electronics

The Council of the Institution of Electrical Engineers, with the encouragement of members of the medical profession, have instituted a Medical Electronics Discussion Group, to provide a forum in which electrical engineers specialising in electronics can meet members of the medical profession to discuss problems in which they have a common interest. The group will hold regular meetings having the nature of colloquia at which subjects coming within the field of medical electronics will be discussed. A committee broadly representing members of both professions will guide the affairs of the group. Any person interested in the group's activities should send his name and address to the Secretary of the Institution of Electrical Engineers, Savoy Place, London, W.C.2, for inclusion in a mailing list for details of the group's activities.

Grave Mistake

It is given to all of us to make mistakes. We all, at different times, try to rub them out, gloss them over or laugh them off. Few of us try to bury them except metaphorically. A man, however, appeared before the magistrates in Yorkshire last week for doing so and was formally convicted of theft.

He had made too many mistakes in making metal track rod ends and the works manager had repeatedly said so, apparently in no uncertain terms. In desperation, the accused had taken the ends home and buried them in his garden. In ordinary circumstances time and rust would have finished the job off for him but he had a stroke of misfortune. He left the house and the new tenant was employed at the same works, a bitter coincidence. She was digging in the garden and found the bits of metal, recognised them as belonging to her employers and returned them. The end of the story was the accused having to pay costs and restitution for his desperate deed.

One part of the story will never get into the papers. One would like to know what the board of the company said to the works manager about his production control methods and checks.

Special Article

BRITISH MILL ROLLS BROAD FLANGE BEAMS

Dorman Long Plant for Universal Sections

THE commissioning of the new universal beam mill at the Lackenby Steelworks, near Middlesbrough, of Dorman Long (Steel) Limited, is an event of considerable importance to structural engineers. Now in full production, the mill rolls a range of beams hitherto available only from Continental and American sources. It provides structural engineers with beams and columns which, compared with the existing British Standard range, are available in a greater number of sizes and weights and in closer modulus steps, and show a valuable improvement in the ratio of strength to weight. The new mill will roll wide flange beams from 36 in deep with flanges 16½ in wide and weighing 260 lb per ft, to 6 in deep by 6 in wide, weighing 20 lb per ft. In addition it is possible for the mill to roll other sections, including the present British Standard range, but as it is anticipated that the new universal beams will eventually supersede the present standard joints in the larger sizes, it is probable that only angles, channels and piling sections will be rolled in addition to the broad flange beams. Sizes, areas, I and Z values for many of the new sections were given in ENGINEERING for November 8, 1957 (p. 601, vol. 184). The mill capacity is 8,000 to 10,000 tons a week.

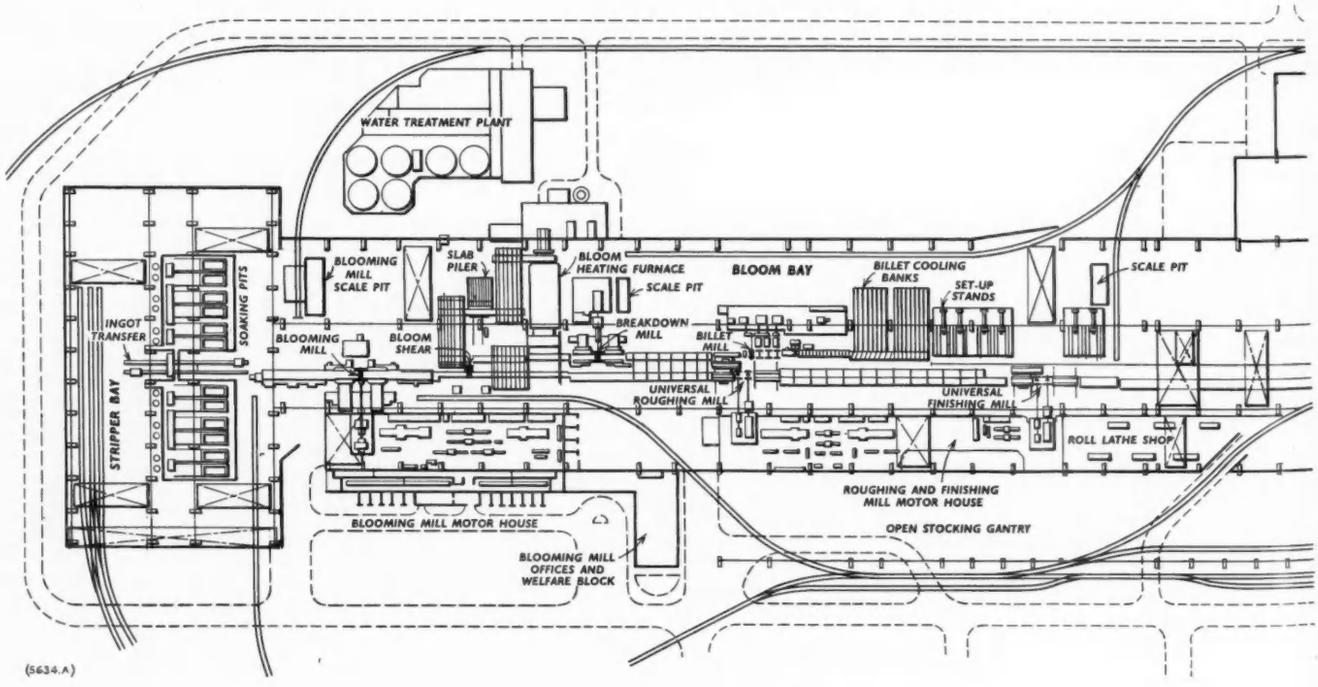
The method of rolling universal beams is fundamentally the same as in the first universal mill developed by an Englishman, Henry Grey, and installed in Luxembourg in 1902. There are four rolls in the mill, two of them horizontal and two vertical, all with their axes in the same vertical plane, and they apply pressure to all faces of the beam at the same time. Suitable adjustments are made to the four rolls between passes to keep the elongations of the flanges and web equal. A separate stand, placed as close to the main stand as possible, and with two rolls only, works the edges of the flanges, squaring them and controlling their length. A better product results from this rolling technique as compared with the two-roll method, as a result of the substantially uniform elongation applied to all parts of the section at the same time. Further, while the two-roll technique requires a generous flange taper the universal beam can be rolled with practically no taper.

Steel for the universal beam mill is supplied by the company's adjacent Lackenby Steelworks, with which the 26 acre mill building harmonises in external appearance. It has been erected and equipped at a total cost of about £20 million, Dorman Long themselves acting as the main contractors and consultants. Scraping of the site was started in April 1954, and the first steel was rolled on 9 January 1958.

Ingot Heating

Ingots, weighing from 4 to 20 tons, are received in their moulds, on rail cars direct from the steel plant. Two stripping cranes are provided in the stripping bay, one of 40 tons lifting and 400 tons stripping capacity, and the other of 20 and 120 tons capacity. Five sizes of ingot are in normal use, and 4,800 tons of ingot moulds are stocked. Ingot lifting dogs are provided on the stripping cranes, and hot ingots are lifted immediately after stripping on to one of two cable-hauled transfer cars and taken to the adjoining soaking pit bay.

Twelve one-way fired soaking pits, built in pairs and in two batteries of six each, provide the heating capacity. Firing is by blast furnace gas from the new furnaces at the company's Cleveland works. Each soaking pit is 26 ft long, 10 ft wide at the centre and 13 ft deep, and has a coke breeze bottom 2 ft thick. They have Escher recuperators, of steel plate construction, for gas and air, the air recuperator lying horizontally, while that for gas is vertical, 75 ft high, and extends through the roof of the building to act as a chimney. These recuperators give a combined preheat to the gas and air of 1,000 to 1,200° C. Each pit lid carries its own lifting and retracting gears, and push-button control is effected from the soaking pit crane cab. Combustion air and gas are cut off while the lid is open.



Blooming

Ingots from the soaking pits are lifted by either of two 20 ton charging machines and placed on a tilting chair leading to the blooming mill. After placing the ingot on the tilting chair the crane driver initiates from his cab a sequence which tilts the chair into a horizontal position, starts the ingot receiving table, and then weighs the ingot. From this point the blooming mill operator takes over.

The blooming mill, with rolls 52 in maximum diameter and 112 in barrel length, is designed to produce not only the shaped blooms required for the universal beam mill, but also to roll rectangular blooms and slabs for the company's plate mills if required. A slab 50 in wide can be rolled and sheared. Twin motors, each of 4,000 h.p., with a base speed of 40 r.p.m. and a maximum speed of 90 r.p.m., drive the mill. They will develop together a maximum operating torque of 2,650,000 lb-ft. Cast steel housings, each weighing about 100 tons, carry the 30 ton mill rolls in resin bonded fabric bearings in totally enclosed chocks. Two Ward Leonard controlled motors, each of 150/300 h.p., drive the 18 in diameter housing screws at 150/300 in per min. Selsyn indication is provided, with the dial in the pulpit. Balancing of the top roll and spindles is hydraulic. Lubrication of the mill is automatic.

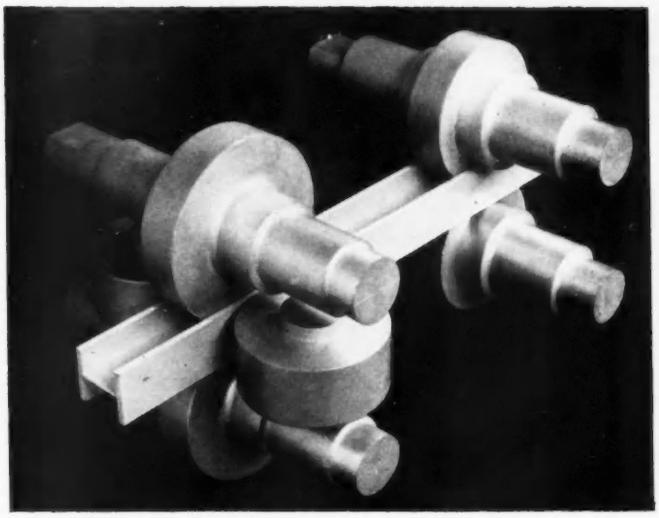
Double side-guard manipulators are fitted, with guards 25 ft long and 4 ft high. All the motions are electrically driven, with the gearing totally enclosed. Fourteen forged steel rollers, 20 in diameter, 10 ft 6in barrel length, spaced at 29 in intervals, and running on roller bearings, comprise the mill tables at the two sides of the mill.

As the preliminary shaping of the blooms takes place in this mill, it is necessary to change the rolls more frequently than in the usual type of blooming mill, and the design therefore allows for rapid roll changing. All the manipulator gear is on the motor side of the mill housing, leaving the opposite side clear for a duplex roll-changing carriage, capable of carrying two complete roll and chock assemblies.

Bloom Shearing

At a distance of 127 ft from the centre of the blooming mill there is an open-sided, hydraulically-operated, up-cutting shear of 1,350 tons capacity. This machine, powered by its own hydraulic pumps and accumulator, can make four cuts at full stroke in 1½ min, repeating after a lapse of 1½ min. It has an adjustable upper head to suit various bloom thicknesses, and will cut a slab 10 in thick and 50 in wide, or equivalent areas up to 19½ in thick. Shaped blades, with motorised table guides, prevent distortion of the cut ends.

From the bloom shear the bloom can take any one of several routes, according to its purpose. Shaped blooms for the larger of the universal beams, which are hot enough to be rolled into finished beams without reheating, go straight to the universal roughing stand, 330 ft away. Smaller shaped blooms can be skidded sideways to a bloom bank and thence to an 80 ton per hour reheating furnace, which takes blooms up to 28 ft long. Reheated blooms can return to the mill line by



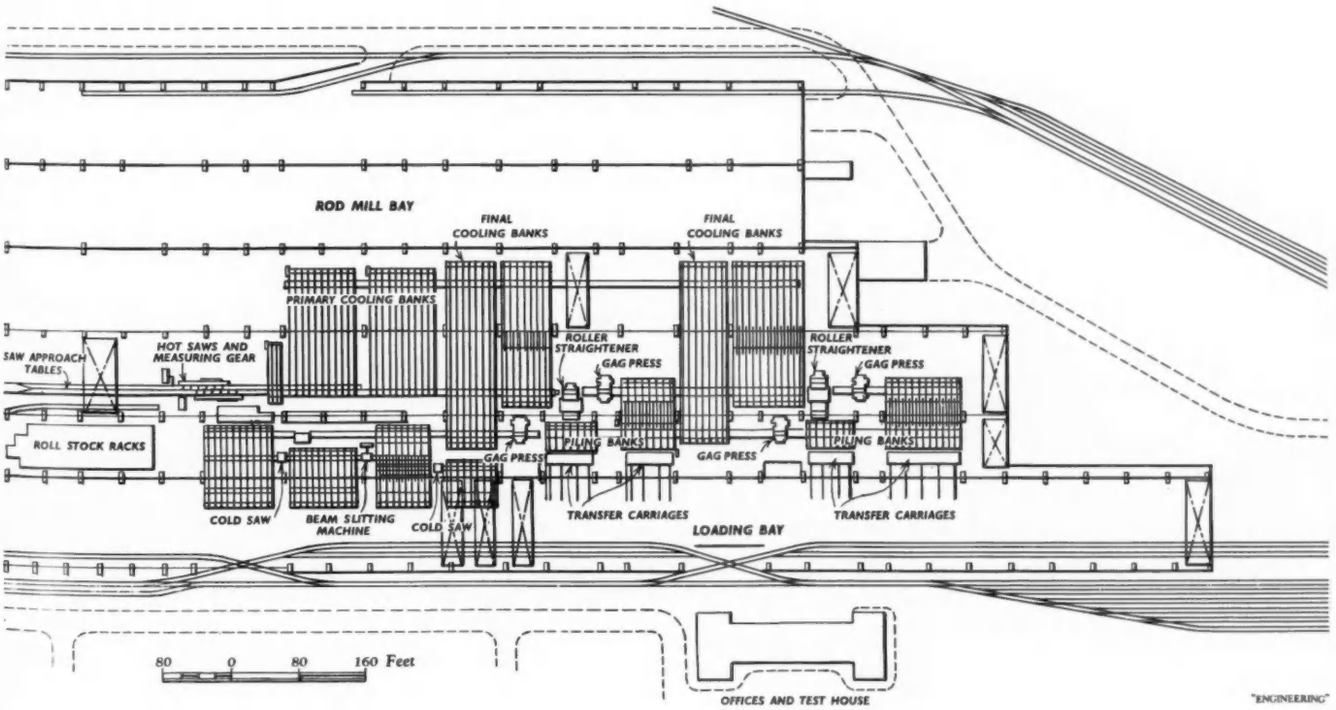
Model indicating basic arrangement of universal beam mill.

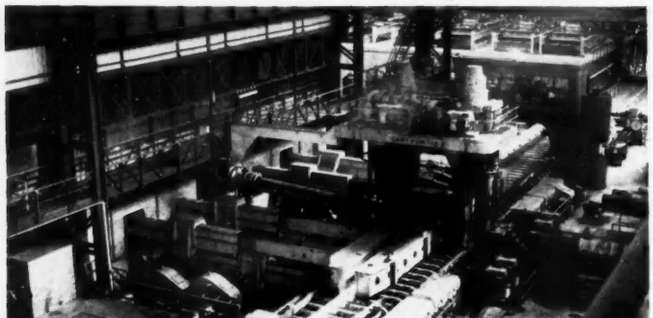
overhead crane, or they can go to a 40 in breakdown mill for the first stage of their reduction to standard sections such as angles or channels; on this set-up the universal stands are converted to structural mills. Alternatively, blooms can be reduced in the breakdown mill ready to pass to an adjacent four-stand billet mill which can roll 4 in blooms to billets from 1 1/16 in to 3⅛ in square, or slabs 2 in to 2½ in thick and up to 12 in wide. Blooms intended for other mills belonging to the company can be taken off without reheating, as can slabs.

Universal Mills

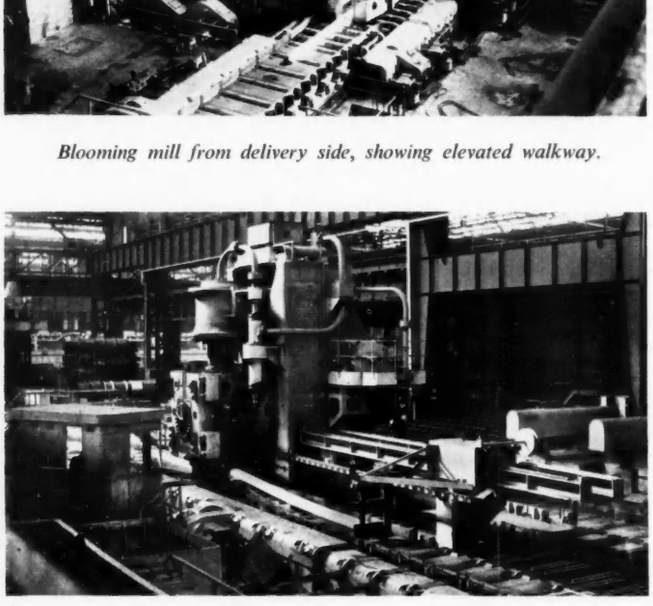
There are two universal mills, arranged in tandem, one for roughing, and the other for finishing. Each mill consists of two stands in tandem, the edging stand with its horizontal rolls coming first, followed at a distance of 13 ft by the main stand with two horizontal and two vertical rolls. The main rolls, 53 in diameter when new, have a plain cylindrical barrel to suit the distance inside the flanges of the beam being rolled. This distance remains constant for a particular basic size of beam, but the flange and web thicknesses can be varied by altering the distance apart of the horizontal and vertical rolls. Fabric bearings are used, and lubrication of all parts of the mill is automatic.

In this type of mill, where the flange edges are not controlled in the main stand, it is important to maintain the piece being rolled at the



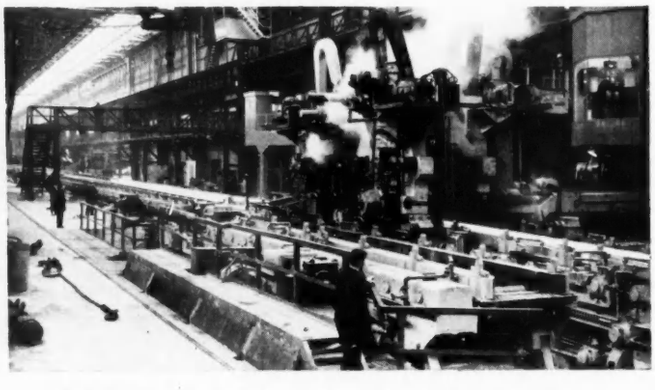


Blooming mill from delivery side, showing elevated walkway.



Bloom shear and measuring gauge. Sheared blooms can take several routes.

Roughing mill. Universal rolling takes place in two mills.



The finishing mill is almost identical with the roughing mill.

correct level relative to the roller tables. On the main stand, therefore, screw control brings the top and bottom rolls closer together between passes while maintaining a constant pass level. Screw gear is also fitted to push the vertical rolls inwards as the beam flange is reduced in thickness. The drive to the main rolls is from a pinion housing with a single motor of 8,000 h.p., 65 r.p.m. base speed, 165 r.p.m. maximum speed, and a torque of 1,615,000 lb-ft at the base speed. There are two rolls each 43 in diameter in the edging stand; they are driven by twin motors, each of 1,350 h.p. at 125/310 r.p.m., and with a maximum operating torque of 285,000 lb-ft.

A novel feature of the universal mills, both roughing and finishing, is the arrangement of the side guides and control of positions of these guides relative to the positions of the horizontal and vertical rolls. Mechanically adjusted guides are fitted, and dials indicate to the mill operator in his pulpit the roll and guide positions. Automatic pre-set positioning of the rolls and guides is under push-button control from the pulpit, and while the mill is working, a schedule can be set on the automatic controlls ready for the next section to be rolled.

For roll changing, the complete stands, roughing and finishing, are lifted out by overhead cranes, the larger of the two having a capacity of 275 tons to deal with the main stand. An area adjacent to the finishing mill position is equipped with seven dummy mill beds, on which complete roll stands can be placed and set up ready for use. An independent, semi-goliath crane serves this area, so it is not necessary to use the large cranes for roll setting.

Hot Sawing and Cooling

After leaving the finishing stand the rolled product can be swept to one side or the other hydraulically to either of twin roller tables leading to hot saws 535 ft and 560 ft away from the finishing mill. Each saw is of the horizontal sliding-frame type hydraulically traversed, with a stroke of 5 ft 10 in. A 500 h.p. motor drives the 72 in diameter saw at a peripheral speed of 21,300 ft per min. Specially designed measuring gear enables each piece to be cut to the length ordered by the customer, at production rates equal to that of the mill.

An arrangement of cooling banks different from that normally used in section mills has been adopted at Lackenby. Instead of a set of banks accepting hot products on one side and delivering cold ones on the other, there are tandem banks, two primary ones taking products from the saws, and four final banks where the cooling is completed. This arrangement makes it possible to sort out the products in such a way as to cut the various lengths ordered, and at the same time achieve the shortest possible discard. When this is done, lengths from different orders may be mixed on the primary banks, but between there and the secondary banks they can be collected together ready for loading for despatch.

All rolled material is straightened, and there are four reciprocating or " gag " presses for the larger sized material and a roller straightening machine for the smaller. Each of the presses is capable of dealing with the largest beam rolled in the mill; simple turnover gear is fitted to the presses so that beams can be straightened on both axes.

A piling bay adjoins the straightening section, and here the beams can be picked up by multiple-magnet cranes and piled ready for loading into wagons. The piles are made up on four transfer cars which, when loaded, are self propelled into an adjacent bay, where the piles are lifted off by crane on to waiting wagons.

Cold sawing and beam-splitting equipment, located adjacent to the piling and loading bays, enable beams and other sections to be cold sawn to length as required. In addition, beams can be split along the web to produce tees, which are suitable for a variety of purposes including serving as upper and lower booms of lattice girders.

Services

Particular attention has been paid to the provision of services and to maintenance. A comprehensive water system provides filtered water to all the roll necks, cooling water for the air filtration systems on the motor houses, and flushing water for mill scale. The water is re-circulated, make-up only being taken from the town mains.

Centralised oil and grease lubrication systems are provided at the mills, there being 50 of these automatic systems in all.

Roll maintenance is catered for by a roll turning shop adjoining the mill bay and containing six 30 in roll lathes. Outside the roll turning shop, but under the same crane, are the roll stocking racks. These occupy an area of 8,000 sq. ft and accommodate 448 rolls in four layers.

A walkway 15 ft above ground, runs the full length of the mill bay, and gives access, by stairs at frequent intervals to all parts of the mill floor. Safe and easy access has been provided by means of gangways and stairs to every part of the building where men must go in the course of their work. Gangways in the roof, for example, give access to the lights, and built-in wheeled trolleys enable the glass in the roof lights to be reached for cleaning.

Research and Development

SOIL BEHAVIOUR DURING SHEAR*

Existence of Critical Voids Ratios

By C. P. Wroth, M.A.†

Synopsis.—The equation obtained by Hvorslev for the shear strength of a saturated remoulded clay can be used to define a surface in a space of three variables given by the normal stress σ', the voids ratio e and the shear stress τ. At any stage in a shear test the values of these parameters (σ', e, τ) form the co-ordinates of a point in this space which traces out a path as the test progresses. The paths taken in undrained and fully-drained tests can be correlated by applying a boundary-energy correction for the work involved in the volume changes of drained test samples. The final portions of all paths define a unique yield surface, and the paths end at points which define a unique line on this yield surface. At the end point of a path the sample is in a state of critical voids ratio, and further unlimited deformation can take place with the values of σ', e and τ remaining unchanged.

This method of presenting results in a three-dimensional form can be extended to cover the case of standard triaxial machines or tests from other equipment, using three comparable parameters. Once the yield surface for a particular soil has been established it is possible to predict the complete test path, provided the initial conditions and degree of drainage are known; furthermore, for all tests except drained ones on heavily over-consolidated clays or dense sands, the peak applied shear stress can be accurately estimated.

NOTATION

The following suffixes are used to denote the specific states mentioned: e for external, f for failure, i for internal, and u for ultimate.

- e Voids ratio
- n Over-consolidation ratio
- p Mean principal effective stress $= \frac{1}{3}(\sigma_1' + 2\sigma_3')$
- q Corrected deviator stress $= (\sigma_1' - \sigma_3')_i$
- u Pore-water pressure
- v Volumetric strain
- w Water content
- x Relative displacement of shear-box
- y Height of sample in shear-box
- ϵ_1 Axial strain of triaxial sample
- μ_o, ν, B Constants in equation (1)
- σ' Effective normal stress
- σ_1, σ_2, σ_3 Principal applied stresses in triaxial system
- σ_1', σ_2', σ_3' Principal effective stresses in triaxial system
- τ Shear stress
- ϕ_o Inclination of straight lines forming Hvorslev surface

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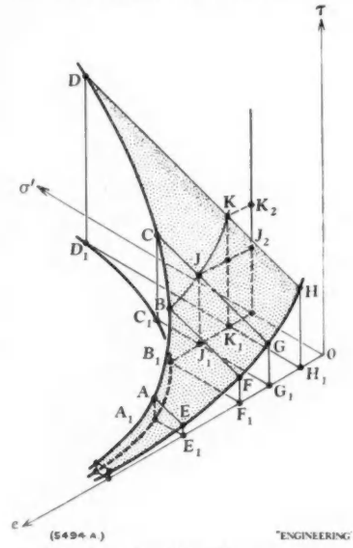


Fig. 1 The Hvorslev surface.

KNOWLEDGE of the shear strength of soils is of fundamental importance to civil engineers, as it forms the basis of the analysis of all stability problems occurring in soil mechanics, such as the design and construction of earth dams, retaining walls, embankments, excavations and footings. The present knowledge of the subject is largely based upon the work of Hvorslev[1] in which he showed that the peak shear stress, τ_f, occurring at failure of a saturated remoulded clay is a function of the effective normal stress σ'_f on, and of the voids ratio e_f in, the plane of failure at the moment of failure. Furthermore this function is independent of the stress history of the clay in question.

Unfortunately Hvorslev's relationship can only be used to predict the strength at failure if the failure values of the normal stress and voids ratio are known; and in most problems it is only the initial voids ratio, prior to the application of any shear stress, that is likely to be known.

Much of the recent research work in the Soil Mechanics Laboratory of the Cambridge University Engineering Department has been conducted in an attempt to improve the understanding and measurement of the volume changes which occur in shear tests on soils, and thereby extend the usefulness of Hvorslev's work. This paper is a brief summary of the most recent and hopeful developments made along these lines.

HVORSLEV SURFACE

The Hvorslev criterion of failure, mentioned earlier, may be expressed for a given soil by the equation

$$\tau_f = \mu_o \sigma'_f + \nu \exp(-\mathrm{B}\, e_f) \quad . \quad (1)$$

where μ_o, ν and B are constants of the particular soil. This equation is satisfied by all possible states of stress and voids ratio when the soil has reached a state of failure in a drained shear test. It is a function connecting the three independent variables σ'_f, e_f and τ_f; and when it is plotted three-dimensionally with right-handed co-ordinate axes (σ', e, τ) it defines a unique surface which will be called the Hvorslev surface.

This surface is shown in the general isometric view of Fig. 1, in which the $\tau = 0$ plane is horizontal with the positive direction of the τ-axis vertically upwards. The points A, B, C, D, E, F, G, H, J and K lie on the Hvorslev surface and their projections on to the three reference planes $\tau = 0$, $e = 0$ and $\sigma' = 0$, have been given the suffixes 1, 2 and 3 respectively.‡ These three projections of the Hvorslev surface are shown in Figs. 2, 3 and 4. In the plan (projection on to the $\tau = 0$ plane) of Fig. 3, the normal consolidation line A_1 B_1 C_1 D_1 is given by

$$e - e_o = -\frac{1}{\mathrm{B}} \log_e \left(\frac{\sigma'}{\sigma'_o}\right) \quad . \quad . \quad (2)$$

where e_o, σ'_o are constants and B is the same as in equation (1). This line represents the loosest packing or greatest voids ratio for any given value of σ' and forms a boundary for the possible values of (σ', e) when $\tau = 0$. Roscoe, Schofield and Wroth[2] have shown that the Hvorslev surface is a ruled surface, formed by a set of lines (shown here as A E, B F, C G, D H) which are all parallel to the $e = 0$ plane and make an angle ϕ_o ($= \tan^{-1} \mu_o$) with the $\tau = 0$ plane.

The shear tests carried out by Hvorslev were stress-controlled, which precluded any investigation of the conditions of a sample after the peak shear stress τ_f had been attained. With the use of strain-controlled shear tests, the yielding of a sample no longer results in sudden collapse at failure, but can continue after the peak shear stress has been reached. Normally this progressive yielding is represented by graphs in which the parameters σ', e and τ are separately plotted against the strain or deformation of the sample. At any instant in the test, however, these three parameters define a point in the domain lying beneath or on the Hvorslev surface, and as the test progresses this point (σ', e, τ) traces out a test path. The direction of this path is governed by the conditions of drainage allowed during the test, which restrict the degrees of freedom from three to two. In general tests are conducted with either full drainage or no drainage.

BOUNDARY ENERGY CORRECTION

In tests with full drainage such as those carried out by Hvorslev, the effective normal stress σ' experienced by the soil particles remains constant, equal to σ'_o say. The test path is therefore constrained to lie in the $\sigma' = \sigma'_o$ plane; such a plane is shown by B J K K_2 J_2 K_1 J_1 B_1 in Fig. 1. As the test progresses the volume of the soil

‡ E, F, G, H lie in the $\sigma' = 0$ plane and coincide with their projections E_3, F_3, G_3, H_3.

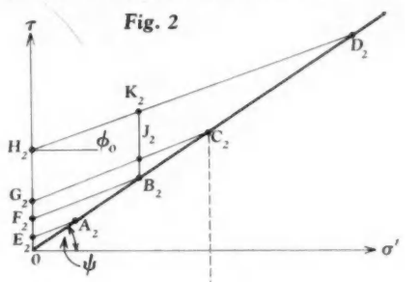


Fig. 2

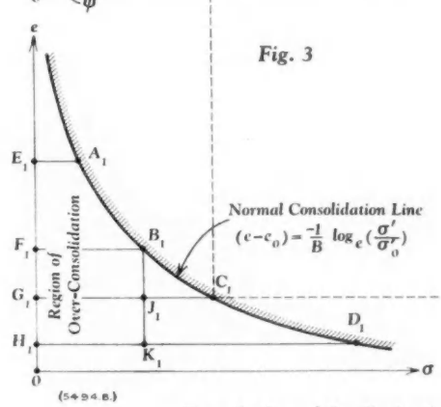


Fig. 3

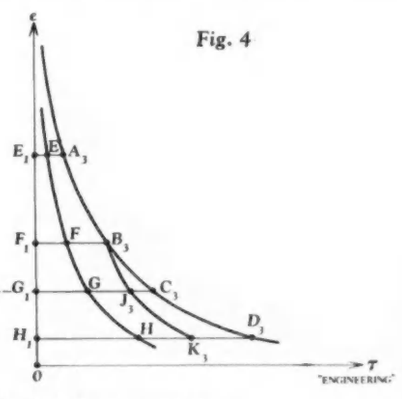


Fig. 4

Figs. 2, 3 and 4 Projections of the Hvorslev surface.

sample and consequently the voids ratio change, and this requires extra work to be done by or against the external stresses which act on the boundary of the sample. The measured shear stress τ can be split into components τ_e and τ_i, where τ_e is defined to be that part of the shear stress which would be just sufficient to provide the work used by the soil sample in altering its volume against the confining pressure. The remainder τ_i is that which provides the work absorbed internally by the sample.

With the convention that τ_e is positive when the sample is expanding, and negative when contracting, the equation

$$\tau = \tau_e + \tau_i \quad . \quad . \quad (3)$$

always holds. For a shear-box

$$\tau_e = \sigma' \frac{dy}{dx} \quad . \quad . \quad . \quad (4)$$

where y is the sample thickness and x the relative displacement of shear-box halves. By observing $\frac{dy}{dx}$ for any point on the test path, τ_e and consequently τ_i can be deduced.

In tests where no drainage is allowed, the volume of the sample remains constant and the test path is constrained to lie in the $e = e_o$ plane while the effective normal stress σ' changes according to the excess pore-water pressure u set up in the soil. Such a plane is shown by G J C C_1 J_1 G_1 in Fig. 1 and this is at right-angles to the full-drainage plane given by $\sigma' = \sigma'_o$. Since the volume of the sample remains constant the boundary-energy correction, $\tau_e \equiv 0$, and the entire work provided by the shear stress is absorbed internally.

When correlating the results of the two different types of test, it is necessary to compare the values of the corrected shear stress τ_i, and not the applied shear stress τ, which have been observed. To emphasise this distinction, the paths traced out by successive values of (σ', e, τ_i) or by directly similar variables will be called loading paths, whereas those traced out by the applied stresses (σ, e, τ) the applied-stress paths.

LINE OF CRITICAL VOIDS RATIOS

Experimental evidence discussed in detail by Roscoe, Schofield and Wroth[2] suggests that the envelopes formed by loading paths from drained and undrained tests on any one soil coincide and form a unique surface. This common surface, called the yield surface, is similar in shape to the Hvorslev surface, but with the important difference in its formation in that it is defined by sequences of points from both drained and undrained tests, whereas the Hvorslev surface is defined by single failure points from drained tests only.

Any one loading path reaches this yield surface and then remains on it, and the question arises as to whether the path ends at any specific point. If such a point exists the sample can theoretically be given further unlimited shear deformation without the values of any of the variables σ', e and τ changing, and the sample will then be in a state of critical voids ratio. Such a definition of critical voids ratio incorporates both the approach suggested by Casagrande[3] based on volume changes in drained tests, and that of Taylor[4] based on changes of effective stress (and consequently strength) in undrained tests.

The end points of loading paths can be expected to define a narrow band or possibly a line on the yield surface. If the loading paths for any soil converge on, and thus define, one unique line, this will be called the Critical Voids Line—or CVR line for short.

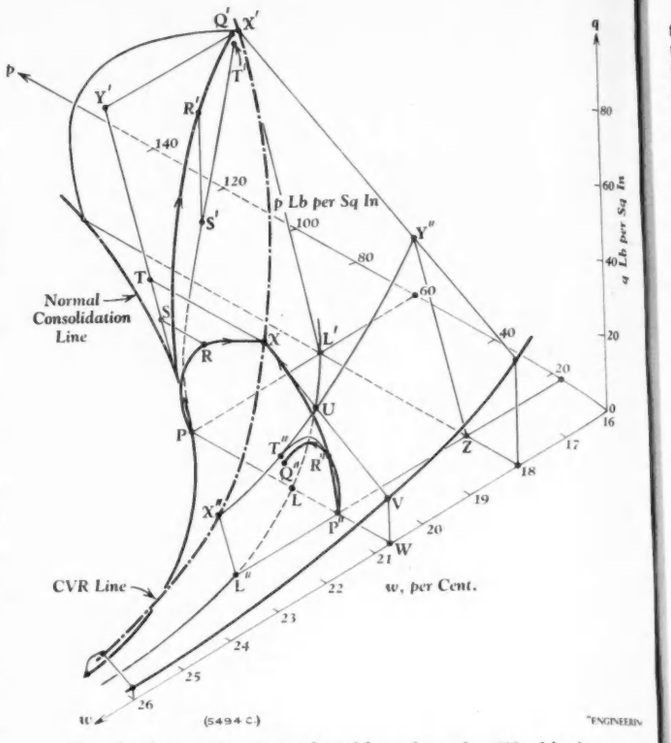


Fig. 5 Isometric view of yield surface for Weald clay.

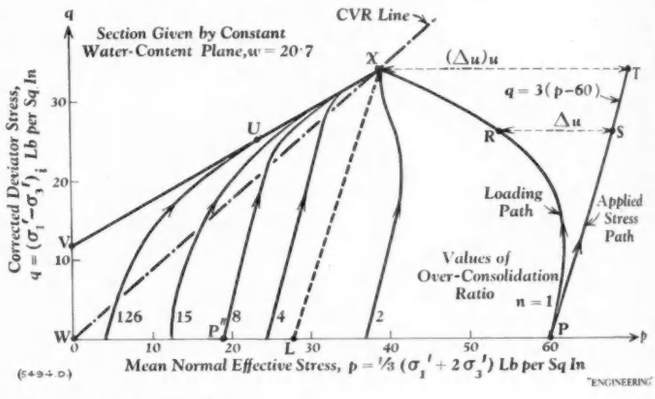


Fig. 6 Section of yield domain for undrained triaxial tests on Weald clay.

Figs. 7, 8 and 9 Paths for drained triaxial tests on Weald clay.

Fig. 7

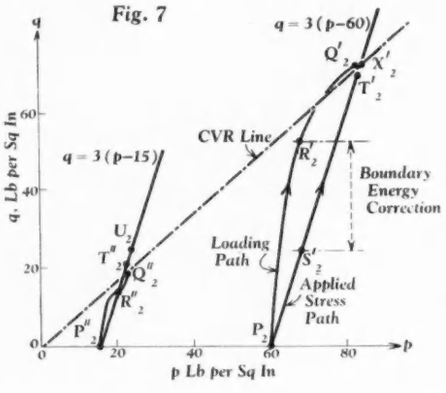


Fig. 8

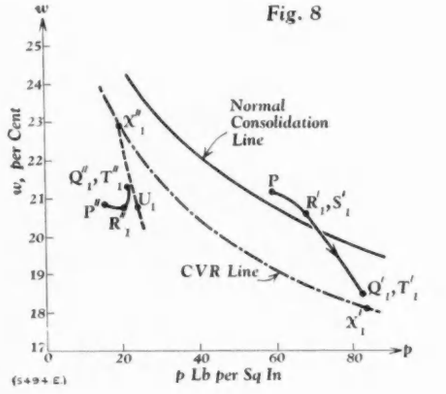
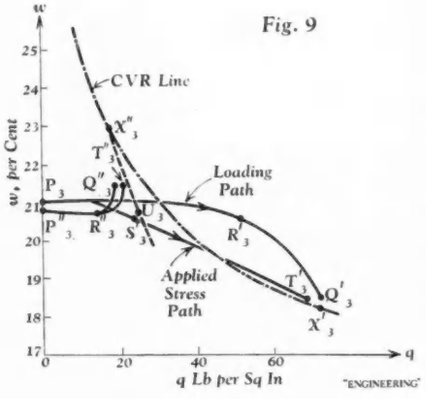


Fig. 9



In practice it is not possible to measure the pore-water pressure set up in a sample which is subjected to an undrained test in a conventional shear-box. In order to obtain any form of correlation between drained and undrained tests it is necessary to use results from the triaxial-compression machine. These should give similar surfaces to those from the shear-box, so long as corresponding parameters are chosen for the co-ordinate axes.

TRIAXIAL TEST RESULTS

The stress parameters chosen for plotting triaxial yield surfaces are the mean principal effective stress $p = \frac{1}{3}(\sigma_1' + 2\sigma_3')$ and the deviator stress $(\sigma_1 - \sigma_3) \equiv (\sigma_1' - \sigma_3')$ where σ_1', $\sigma_2' \equiv \sigma_3'$, and σ_3' are the effective stresses defined as usual. Besides being straightforward functions of the test data, these variable parameters are special cases when $\sigma_2' = \sigma_3'$ of general symmetrical mathematical expressions. The parameter p is the first invariant of the stress tensor, while $(\sigma_1' - \sigma_3')$ can be derived directly from the second invariant of the stress-deviation tensor. Consequently, these parameters are independent of the choice of reference axes in a general triaxial-stress system.

In addition, results from any other type of

triaxial apparatus (such as the plane-strain triaxial machine developed by Wood[5] or the thick cylinder apparatus of Kirkpatrick[6]) can be plotted on the same axes, thus affording a direct comparison between the sets of results. The choice of the third variable is essentially unchanged and lies between the voids ratio, the porosity or the water content, whichever is most convenient. (For partially saturated soils, the voids ratio should be used in preference to the water content because the properties of the yield surface appear to be primarily connected with the packing and loading of the soil particles themselves, and not with the fluid contained in the particle matrix.)

For drained tests a boundary-energy correction must be applied to the deviator stress; as before, this is defined by the equation

$$(\sigma_1' - \sigma_3')_e = (\sigma_1' - \sigma_3')_e + (\sigma_1' - \sigma_3')_i \quad (5)$$

into which must be substituted

$$(\sigma_1' - \sigma_3')_e = \sigma_3 \frac{\mathrm{d}v}{\mathrm{d}\epsilon_1} \quad . \quad . \quad (6)$$

(where v = volumetric strain and ϵ_1 = axial strain) because the external work is done by or against the cell pressure σ_3. To emphasise the correction and for convenience the corrected deviator stress $(\sigma_1' - \sigma_3')_i$ will be denoted by the symbol q.

A comprehensive set of triaxial test results on saturated remoulded samples of Weald clay has been carried out by Gilbert[7] and kindly made available to the author. The results have been replotted in the manner outlined above and show a common yield surface containing a closely defined CVR line for both the drained and undrained tests; these data are shown in the isometric view of Fig. 5. These are now described in some detail.

UNDRAINED TESTS

The loading and applied-stress paths for an undrained test will lie in a section of the (p, w, q) domain made by the plane w = constant = w_o. When a sample of Weald clay is normally consolidated under an all-round pressure of 60 lb per sq. in, the equilibrium water content is 20·7 per cent. This condition of the sample is represented by the point P in Fig. 6 and all points in this diagram lie in the plane $w = 20{\cdot}7$.

If the applied-stress path for a conventional undrained test (σ_3 constant, σ_1 increasing) on this sample is plotted on the same axes as p and q it will be a straight line making an angle $\tan^{-1}3$ with the p-axis and passing through P. If at any stage a small increment of any variable x is denoted by δx and the total change since the start by Δx, then $\delta\sigma_3 = \Delta\sigma_3 = 0$; and so every

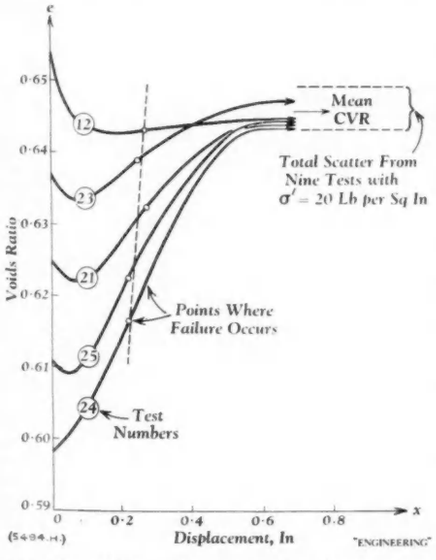
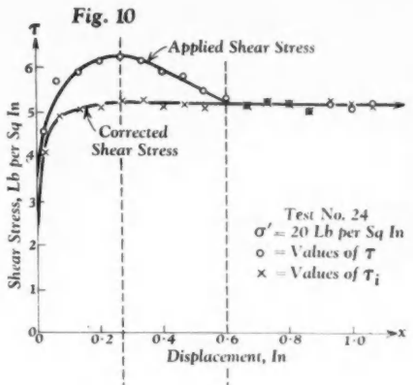
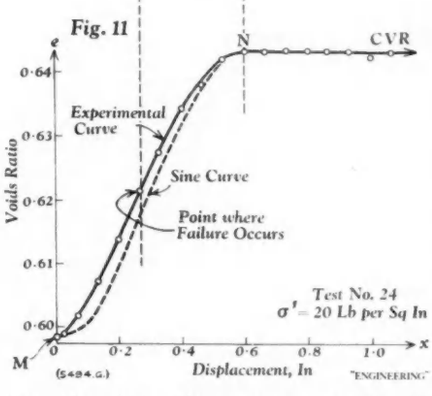


Fig. 12 Voids ratio curves for simple shear tests on steel balls with a normal stress of 20 lb per sq. in.





Figs. 10 and 11 Shear stress curves (Fig. 10) and voids ratio curve (Fig. 11) for simple shear test on steel balls.

increment of applied stress in the p-direction of $\delta\left[\frac{1}{3}(\sigma_1 + 2\sigma_3)\right] = \frac{1}{3}\delta\sigma_1$ is accompanied by an increment in the q-direction of $\delta(\sigma_1 - \sigma_3) = \delta\sigma_1'$, i.e., three times as great. Hence the applied-stress path is represented by PST and given by $q = 3(p - 60)$.

The loading path is shown by PRX, of which any point R has the same ordinate as the corresponding point S of the applied-stress path since $(\sigma_1' - \sigma_3') \equiv (\sigma_1 - \sigma_3)$. But the abscissa of R is $\frac{1}{3}(\sigma_1' + 2\sigma_3') = \frac{1}{3}(\sigma_1 + 2\sigma_3) - \Delta u$ and is therefore less than the abscissa of S by the pore-water pressure Δu. The loading path ends at X when the sample has reached its ultimate state in which the stress parameters have reached values such that the particular voids ratio (or water content) of the undrained sample has become critical. These ultimate values are given the suffix u.

Also shown in Fig. 6 are the loading paths of other samples with the same water content but differing values of the over-consolidation ratio n. (This ratio is defined as that of the maximum consolidation pressure to the final consolidation pressure; i.e., if in Fig. 3, a sample has been normally consolidated to D_1 and then allowed to swell to J_1, then $n = \left(\frac{\text{pressure at } D_1}{\text{pressure at } J_1}\right)$. Each loading path ends at or very close to X, and each applied-stress path is of gradient 3 and starts from the appropriate point on the p-axis. Those samples with paths starting from the right of L develop positive pore-water pressures, and those to the left end with negative values. For a sample with paths starting at L itself, the applied-stress path is L X so that $(\Delta u)_u = 0$, and therefore L separates the samples with positive values of $(\Delta u)_u$ from those with negative.

The loading paths for tests with $n > 3$ become tangential to the straight line V U X, with P R X U V forming the boundary for all loading paths in this one plane. This plane together with the loading path for the normally consolidated sample starting from P and that for the sample with $n = 8$ starting from P″, are shown in the isometric view of Fig. 5.

Sections of the yield domain made by other values of the water content are of identical shape but of different size. However, as w varies, the locus of P is the normal consolidation curve of the clay so that the dimensions of any one section vary logarithmically with its water content, cf. equation (2). The boundary P R X U V traces out the yield surface, with the part traced by V U X being similar to the Hvorslev surface; the remainder is formed by the curved profile P R X of normally consolidated samples. Furthermore, the curved ridge separating these two parts is the C V R line, X″ XX′.

DRAINED TESTS

Consider a sample which has been normally consolidated under an all-round pressure of 60 lb per sq. in having reached equilibrium at P in Fig. 5. As in the case of the undrained test, the applied stresses are such that any increment in the q-direction is 3 times that in the p-direction so that the applied-stress path is confined to the plane $q = 3(p - 60)$, which will be called the applied-stress plane. This is shown by P S T Y′ X′ L′ in Fig. 5, and corresponds to the full-drainage section of the Hvorslev domain (B J K K_2 J_2 K_1 J_1 B_1 in Fig. 1), though instead of being "vertical" it cuts the $q = 0$ plane at an angle of $\tan^{-1}3$.

The applied-stress path P S′ T′ can be seen in Fig. 5 and in the projected views of Figs. 7, 8 and 9, with the appropriate suffixes given to the points. In the plan of Fig. 8 the point P is outside the normal consolidation line which has been taken as the mean of several tests; the discrepancy shown by this test gives the order of experimental error involved in measuring the water contents of individual samples.

The loading path P R′ Q′ is obtained from the applied-stress path by applying the boundary-energy correction, represented by R′ S′ by means of equations (5) and (6). The correction is solely to the value of the deviator stress, so that R′ S′ is a vertical offset of magnitude $\sigma_3 \frac{\mathrm{d}v}{\mathrm{d}\epsilon_1}$ between the two paths (in contrast to the horizontal offset R S of magnitude Δu between the two undrained test paths). In such a test the sample contracts throughout so that the correction is always negative, and the loading path is above the applied-stress path. The paths necessarily coincide in the plan view of Fig. 8. (This particular sample quoted by Gilbert was still showing a small decrease in volume when the test was stopped, and the respective paths had only reached Q′ and T′ and had not arrived at X′ on the C V R line, where they are both expected to end.) Throughout the test the sample gains in strength, while it expels water from the voids, and the peak value of the deviator stress, defining failure, occurs at the ultimate state.

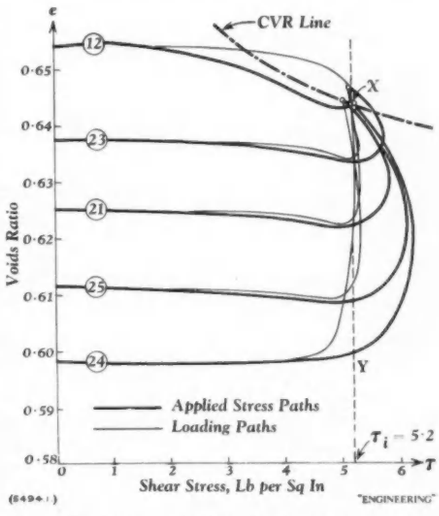


Fig. 13 Test paths for simple shear tests on steel balls with normal stress 20 lb per sq. in.

A different sample with over-consolidation ratio of 8 reaches equilibrium prior to testing at P″ in Fig. 5. The applied-stress plane for a drained test on such a sample is P″ L″ X″ T″ U Y″ Z, given by $q = 3(p—15)$ and cuts the C V R line at X″ corresponding to a higher water content than P″. Consequently the sample must expand for the test paths to approach X″, in direct contrast to the normally consolidated sample just considered.

The loading path P″ R″ Q″ and applied-stress path P″ R″ T″ are plotted in Fig. 5 and in the projected views of Figs. 7, 8 and 9. These paths are expected to become tangential to X″ U and end at X″. However, this test was stopped shortly after failure had occurred, when the sample was still expanding rapidly.

In practice the observed test paths will not reach X″. This is because an expanding sample prefers to distort non-uniformly if possible with a minimal zone of deformation, in order to keep the extra work used in dilatation as small as possible. A triaxial sample can and probably

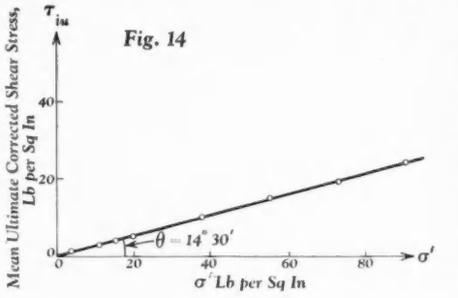


Fig. 14

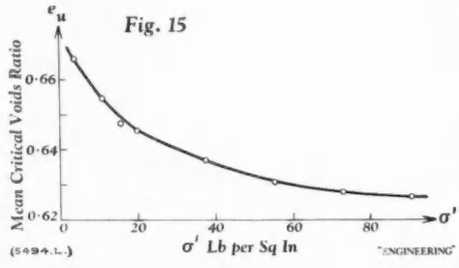


Fig. 15

will do this in these circumstances; consequently the observed values of the parameters (and especially the water content) are mean ones for the whole sample and are not representative of the small zone that is actually deforming and reaching the ultimate state. Thus the recorded value of w is necessarily an under-estimate.

In contrast, contracting samples give reliable results, since if any zone of greater distortion develops then it gains in strength and further deformation of the sample is taken up by the weaker remainder, until uniformity is restored.

The applied-stress plane for the point L cuts the C V R line at X within the same w-plane (see Figs. 5 and 6), so that a drained test on a sample with paths starting at L should show no net volume change. The point L then divides the samples that contract from those that expand; and it is the same point (see Fig. 6) as that which differentiates in undrained tests between those samples with positive and those with negative pore-pressure changes.

The locus of L is the curved line L″ LL′ on the $q = 0$ plane of Fig. 5 and is in fact an oblique shadow of the C V R line. This line divides all possible samples into two distinct categories. All those on the wet side (i.e., further from the origin) are "under-packed" or "over-loaded"—they will contract and increase their density of packing in a drained test, or develop a positive pore pressure and transfer some of the load to the pore water in an undrained test. Those samples on the dry side are "over-packed" or "under-loaded" and will behave in a directly opposite manner.

Assuming then that the yield surface and C V R line apply to a clay, it is possible to predict the ultimate state of any sample in either type of shear test. For an undrained test it will be the intersection of the appropriate water-content plane with the C V R line; and for a drained test it will be the intersection of the appropriate applied-stress plane with the C V R line. In addition, for all but heavily over-consolidated samples, the failure state coincides with the ultimate state on the C V R line, so that the failure values of the parameters are simultaneously predicted.

For drained tests on heavily over-consolidated samples, the peak shear stress occurs well before the ultimate state because of the large positive va ue of the boundary-energy correction. Since this is directly dependent on the rate of dilatation, it can only be estimated by means of further assumptions or approximations, and such a possibility is mentioned in the next section.

SIMPLE SHEAR TESTS

The difficulty in obtaining reliable information at the end of a drained test on an over-consolidated clay has already been mentioned. In the case of silts, sands and other cohesionless granular media the difficulty is more acute on account of the larger volume changes which are likely to take place.

With the view that more accurate results could be obtained Roscoe[8] designed an apparatus for applying uniform simple-shear strain to a soil sample. This simple-shear apparatus has been developed and used by the author[9]; and some of the test results are briefly described in the following paragraphs.

These tests were all "drained" ones (i.e. allowing volume changes) on a mass of dry steel balls of 1 mm diameter. The balls were placed in the apparatus with different densities of initial packing, which in all cases was random. The parameters used for plotting the loading paths are the effective normal stress σ', the voids ratio e and the corrected shear stress τ_i.

Fig. 10 shows the result of a single simple-shear test with the applied shear stress plotted in the normal manner against the relative displacement x of the two parts of the shear apparatus. The corrected shear stress, τ_i, is also plotted, and is seen to be practically constant for all but the initial part of the test. Directly below Fig. 10, in Fig. 11, the volume-change curve is plotted conventionally as voids ratio against displacement. At the point N the volume change has ceased with the sample having dilated to the voids ratio which is critical for the particular loading condition ($\sigma' = 20$ lb per sq. in). At this stage the boundary-energy correction is zero, and thereafter the values of τ and τ_i coincide.

The volume-change curve (between M and N) is very closely sinusoidal,* and this empirical approximation is borne out by Fig. 12 in which the voids ratio curves for five tests are plotted, starting with different densities of packing but all with the same value of σ'. These tests reach a final state within a narrow band closely defining the mean critical voids ratio for this fixed value of σ'. In addition the points at which failure occurs have been marked and these are seen to lie on a straight line.

The loading and applied stress paths for all these samples remain throughout each test in the plane $\sigma' = 20$, as is shown in Fig. 13. Within small limits of experimental error all paths end at the one point X, which must lie on the CVR line. Also, the loading paths form a common envelope XY (the straight line $\tau_i = 5{\cdot}2$) which becomes the section of the $\sigma' = 20$ plane with the yield surface.

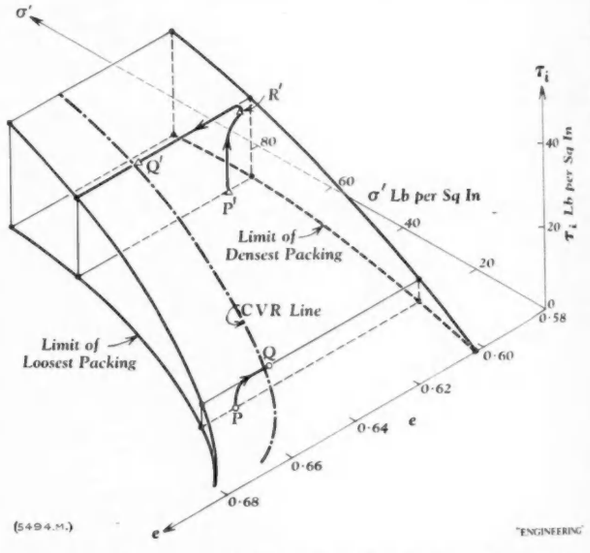
For sets of tests with other values of σ' the co-ordinates (τ_{iu}, e_u) of X trace out the CVR line. These mean ultimate values defining X are plotted separately against σ' in Figs. 14 and 15. The upper figure is an elevation of the CVR line and, in fact, of the complete yield surface which is at an angle $\theta = 14° 30'$ to the $\tau = 0$ plane. The lower figure is a plan view of the CVR line which becomes straight if σ' is plotted on a logarithmic base, and this suggests a similarity of behaviour between the steel balls and the Weald clay.

The yield surface for the steel balls is shown isometrically in Fig. 16 with two specimen loading paths. The first starts from a loose state at P, rises vertically to the yield surface and then traverses the surface, as the sample contracts, to a point Q on the CVR line. The second starts from a dense state at P′, passes through a minimum voids ratio at R′ and then traverses the surface in an opposite direction while the sample expands; it also reaches the CVR line, at Q′.

Making three simple assumptions about the behaviour of the steel balls, based on these results, the applied-stress path for any drained test can be predicted mathematically. These assumptions are: (i) in any drained test, for a fixed value of σ', τ_i is effectively constant (Figs. 10 and 13); (ii) the voids ratio curves are sinusoidal in shape (Fig. 12); and (iii) the strain or displacement to failure, for any fixed σ', is constant (Fig. 12). The mathematical details cannot be included here, but are given elsewhere by the author,[9] where it is also shown that there is good agreement between the predicted and measured applied-stress paths up to the stage when failure occurs.

Figs. 14 and 15 (left) Elevation (Fig. 14) and plan (Fig. 15) of CVR line for steel balls.

Fig. 16 (right) Isometric view of yield surface for steel balls.



CONCLUSIONS

By plotting the results of shear tests on soils in the three-dimensional method outlined above, and tracing the various stages of a particular test by a loading path, it is possible to discover whether the soil displays the characteristics of a unique yield surface and a unique CVR line. For those soils that do—and this appears to be the case for a wide variety of granular materials, both cohesive and cohesionless—the ultimate stage of any test can be accurately predicted. For all but drained tests on heavily over-con-

* Reynolds[10] suggested such an expression for the volume change caused by the distortion of a mass of equal spheres; but gave neither theoretical nor experimental justification for it.

solidated clays or dense cohesionless media, this ultimate state is synonymous with the failure state, so that the peak applied shear stress follows immediately. For the particular case of drained tests on dilating media, some simple relationship between the volume change and strain must be assumed to hold (as that taken for the steel balls in the last section) before an accurate prediction of the peak applied-shear stress can be made.

Acknowledgments.—The author wishes to thank Mr. K. H. Roscoe (under whose direction the research work was carried out) and also Mr. A. N. Schofield for their great assistance in all aspects of the work which is outlined above. He is also most grateful to Professor A. W. Skempton and Dr. G. D. Gilbert for granting permission to quote the Weald clay results.

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Continuing **Research and Development**

AERODYNAMIC ADVANCES SINCE 1946

As recorded in last week's issue, the first Daniel and Florence Guggenheim Memorial Lecture was given in Madrid on 8 September by Dr. Theodore von Kármán, on "Some Significant Developments in Aerodynamics since 1946." Von Kármán's lecture took the form of a broad survey of recent work, covering the field of aerodynamics, presented with the typical von Kármán light touch—which, unfortunately, cannot be reproduced in print in the condensed extracts given below. The full paper will be published later in the Proceedings of the First International Congress in the Aeronautical Sciences (Pergamon Press Limited).

It is remarkable how many useful conclusions for aircraft design can be derived from the so-called linear theory of supersonic flow which, after all, is nothing else than "acoustics," i.e., it is based on the assumption that the flow is composed of a uniform parallel flow and a pertubation flow of small magnitude.

The linearised wing theory made it possible to arrive at a series of important results concerning the minimum drag of supersonic wings. The drag of a symmetric flat wing of given planform reaches a minimum if the thickness is distributed over the planform in such a way that the drag per unit volume is equal for every wing element. The optimum lift distribution over a given planform is such that the downwash is constant over the planform. For triangular wings with subsonic edges the minimum drag due to lift is obtained by using negative span-wise camber over most of the planform. It is interesting that this idea was used in the design of the wing of the Convair B-58 bomber (the Hustler). Experimental results show that the "conical camber" produces leading-edge suction and thus essentially reduces drag.

With the increase of the speed of flight, aircraft have become more and more slender; large aspect ratios have disappeared, and now aircraft consist of long bodies and wings of small aspect ratios. For such cases the application of linearised theory had to be revised. In order to simulate the flow around bodies which are neither thin wings nor axi-symmetric bodies, multipoles have to be introduced.

A great simplification was achieved by extending the classical airship theory to slender bodies in general both for subsonic or supersonic speeds. The flow around a slender body (wing or aircraft) can be considered as a superposition of a parallel uniform flow on a sequence of two-dimensional flows in planes perpendicular to the flight direction; whereas for wings of large aspect ratios, it was assumed that the flow in planes perpendicular to the wing axis could be identified with a two-dimensional flow with circulation around the wing section. The slender body theory in general gives a better approximation to the pressures, forces and moments acting on the system than the pure linearised theory.

THE MARILYN MONROE BODY

We shall now consider interference effects between the wing and the body structures of the aircraft necessary to carry payload, passengers or fuel. The most significant example of favourable interference is the arrangement popularly known as the area rule. The resulting flow around the body structure in a low-aspect-ratio wing at large distances can be represented as originating from singularities distributed along the axis. Hence the drag can be considered as caused by an equivalent body of revolution. Now, as far as minimum drag is concerned, the shape of the most favourable bodies of revolution is theoretically known. Thus the components of the aircraft can be arranged so that—at least for a certain Mach number—the equivalent body of revolution approaches the shape corresponding to minimum drag. This leads, for example, to the conclusion that in the case of nacelles arranged near the fuselage the additional drag of the nacelles can be compensated by a reduction of the diameter of the fuselage in the appropriate section. We obtain in this way the shape of the fuselage known popularly as the "Marilyn Monroe body." The name "area rule" originates from the fact that, for a flow near Mach I, the section of the equivalent body of revolution is simply equal to the sum of the areas cut out by a plane laid through the section considered.

Another class of interference phenomena makes it possible to create favourable interference by reflection of compression and expansion waves on components of a lifting system. An example is represented by a combination of a horizontal delta wing and a vertical surface of wedge shape arranged below the wing parallel to the flight direction. One can transfer the pressure created on the surface of the vertical wedge to the lower surface of the wing. Thus the total lift is increased, and the resulting lift/drag ratio is more favourable than for the case of a simple horizontal wing, which furnishes the same lift.

Concerning aeroelastic problems like flutter at high flying speeds, the "piston theory" assumes that the magnitude of the reaction of a high-speed flow on a wing surface at every instant can be approximated by considering the one-dimensional motion of an air column under the action of a moving piston. It seems that for Mach numbers greater than 1·5 this approximate theory furnishes useable results and greatly simplifies the computations.

NON-LINEAR FLOW

Two problems in which the equations of flow are evidently non-linear are transonic and hypersonic flow.

In the transonic case, the difference between flight velocity U and sound velocity c, i.e., the quantity $(U - c)$ is small in comparison with either U or c. It is known that, at least in the case of non-dimensional flow for the potential, we arrive at a relatively simple non-linear equation called Tricomi's equation from which very useful results for computation of transonic flows around wings and bodies can be obtained. On the other hand, the problem of uniqueness of the solution has not made sufficient progress in the last ten years.

The hypersonic speed range is characterised by the fact that the sonic velocity c is small compared with the flight velocity U. The interest in this speed range was recently very much enhanced by the problems connected with missile design, especially the design of nose cones.

Experimental investigations show that, for example, in the case of a thin wedge exposed to very high Mach numbers, a shock starts from the front of the wedge; and inside the space behind the shock one sees an essentially inviscid flow-domain and a boundary layer. This phenomenon was the subject of a great number of investigations. Since in the case of a thin wedge the curvature of the attached shock is small, the vorticity behind the shock may be considered small. However, in the case of the blunt body the problem is much more difficult. We obtain a stagnation point and a subsonic vortex flow, which is very difficult to compute. Near the stagnation point the shock line follows closely the shape of the body. Since at very high Mach numbers the shock surface is very near to the body surface, we essentially have a phenomenon very similar to that assumed by Newton

Continuing Research and Development

in his theory of fluid resistance. Recently an ingenious method has been developed to solve approximately the problem of determining the shape of the shock. Known as the blast-wave theory, it considers the stationary flow as composed of a system of non-steady flows. The non-steady flows are similar to the blast waves computed for the case of a strong explosion starting from a point.

BOUNDARY LAYER

Recently the theory of the laminar boundary layer has made essential progress in the domain of compressible fluids. In fact, the equations of the compressible boundary layer have been reduced by a clever transformation of variables to the same form in which the equations of the incompressible boundary layer appear.

Considering the boundary layer problem for hypersonic flight, in the case of a blunt body the heat transfer is of great interest. Owing to the high temperatures behind the shock wave, dissociation of the air has to be taken into account. Then one can choose between the assumption of chemical equilibrium in every layer, or a frozen value of degree of dissociation—for example, that corresponding to the maximum temperature—or also the assumption of a certain rate-law for the dissociation and recombination.

In the case of a flat plate, one finds that there exists a shock-wave boundary-layer interaction which may, especially at low Reynolds numbers, cause a considerable increase of the static pressure along the plate. This effect may be also originated by the fact that the front edge of the plate is not mathematically sharp; it has always a certain thickness.

Considering transition from laminar to turbulent boundary layer, the mathematical theory shows excellent agreement with experiment as far as the damping or the increasing of oscillations are concerned. However, we do not really understand the mechanism of transition.

The theory of turbulent boundary layers at supersonic speed is not in very good shape. Especially, great uncertainty exists concerning the magnitude of the heat transfer as compared with the incompressible case; and the statistical theory of turbulent motion is not yet satisfactory.

"Heavenly turbulence"—the turbulent phenomena in gas clouds of cosmic dimensions—has fascinated the imaginations of quite a number of mathematicians, astronomers and aerodynamicists. The combination of mechanical, thermal and electromagnetic forces may also have a bright future in applications to propulsion devices. It appears that aerodynamics is not a science which can be put on the shelf as an obsolescent branch of the physical sciences. Of course, aerodynamicists may have to become familiar with the methods and results of many sister sciences.

Further reports on the Madrid Congress will appear in subsequent issues.

Metals and Materials

QUALITY CONTROL *of Tube Products* REDUCES WASTE

Within five months of the introduction of quality control at the new tube factory of Venesta Limited at Silvertown, London, E.16, the margin of scrap, although small, has been reduced by 50 per cent.

Quality control was introduced at the Silvertown plant with two main objectives: (i) the continual observation of much finer tolerances throughout every production run; and (ii) the maintenance of higher standards of quality than those demanded by the customer. Moreover, it was intended that the system of quality control would ensure a consistent standard for every tube as regards dimensions, wall thickness, weight of coating, and so on.

At the same time, investigations into the causes of scrap showed that it could be largely attributed to three reasons: operator failure (the human element); mechanical failure; and, deviations in processing.

Now, it is possible not only to discover why a failure occurred, but how to anticipate it before it happens and take action to avert serious trouble.

CONTROL OF DIMENSIONS

Previously the frequent inspection checks at various stages of production did not attempt to provide the reason for a failure; nor were they used to furnish information on which an analysis of performance could be based. It is now recognised that the essence of quality control lies not simply in a series of isolated inspection checks, but in recording the trend of performance as indicated by these checks over a given period or number of tubes tested.

To-day, of a team of 14 static and mobile inspectors, no fewer than seven are fully engaged on quality control. These experts are in charge of some nine constant, repetitive tests, which are made at selected stages of manufacture, the conditions of test varying according to the different materials used. Intervals between tests range from ten minutes to an hour. Some tests fluctuate in frequency according to the type of inspection involved, others take place at regular intervals through the day.

One inspection, for example, is for dimensions and is made every half an hour involving the assessment of six different measurements on each tube to within tolerances of from 0·002 in to 0·030 in. These tests are standard, and are made to determine whether a machine is running towards or away from a tolerance. Special tests, involving much finer tolerances of from 0·0025 in to 0·003 in are also carried out to determine the thickness of tube membranes when these are used.

Special attention is given to control variation in the thickness of the tube wall. Previously this was checked by taking a single micrometer reading of a double wall thickness. Venesta standards now demand a measurement of the complete surface area of the tube. This is carried out by means of a comparator to within 0·001 in.

CHECKS ON FINISHING COATS

Coating weights are rigorously checked. Every morning an inspector makes a series of tests at ten-minute intervals for one hour to check film thickness. Viscosities, room temperature, and coating machine temperatures, are all carefully noted in these inspections, which continue on a declining time scale at intervals of every hour until mid-day, then increasing in frequency to every half an hour towards evening. To maintain consistency, the enamelling machine is kept in continuous operation throughout the day, including the lunch interval.

Seepage test in progress on membrane-type nozzles. One of many quality-control tests applied by Venesta Limited at their new tube factory.

In assessing coating weight, a measured area of a tube is first cut and weighed with the enamel on. The coating is then stripped, the tube area re-weighed, and the reduction in weight being recorded. Lacquer tests, however, are done differently. Here, the first operation is to weigh a complete tube, after which it is lacquered, stoved, re-weighed, the increase in weight being recorded.

ELECTROLYSIS TEST

The three different types of internal coating used at Venesta—Araldite lacquer, wax coating and vinyl lacquer—are all subjected to the same electrolysis test. This consists in passing a current at low voltage through a solution of copper sulphate contained in the tube under test. Any deposit left is shown by a discoloration of the metal, the efficiency of the coating being recorded against a calibrated scale.

Seepage checks on membrane-type nozzles are made half-hourly by subjecting sample tubes to a compressed-air test while immersed in water; this enables the most minute fracture to be detected instantly. This method is also used to test wadless closures, and as a check for the perfect fitting of plastic nozzles.

The ability of a tube to withstand bursting pressure is assessed by means of a particularly drastic hydraulic pressure test in which tubes are filled with water and subjected to pressure until they burst. The bursting pressure point, which is indicated, must always exceed the limits officially required. In this test, the factors affecting a tube's efficiency are wall thickness, tool fatigue, type of metal, and the type of tube. To arrive at a satisfactory conclusion, conditions are constantly permutated, and the general reaction noted against the changes made. Although this is a test intended principally for soft metals, it is also applied to aluminium tubes as a standard quality-control inspection.

Among other tests applied are those to ensure flexibility of the enamel, resistance to chemical attack—including total immersion in alkalis and soap solutions, crushing tests, and one to ensure that the cap is not screwed too tightly.

By the stringent application of quality control in this way, Venesta Limited have achieved the double objective of setting a higher standard in collapsible tube manufacture, and reducing the amount of scrap.

Marketing

AMERICANS IN EUROPE

The Chase Manhattan Bank of New York have published a booklet entitled *The New European Market—What it means to US Business*, which analyses in considerable detail the trend towards the integration of the economics of Western Europe and attempts to forecast its impact on United States industry. The opening sentence shows clearly that it is to be taken seriously: "The movement towards closer economic integration in Western Europe could turn out to be one of the most significant economic developments of our time. As such it poses a series of challenges and opportunities to United States business." The precise nature of the developments that are unfolding is far from clear at this stage, but despite the uncertainties the bank takes the view that "there will be substantial changes in the economic structure of Europe over the next ten to twenty years." Throughout the booklet runs the feeling that the speed of the change may be much greater than currently anticipated.

The comparison of the European Economic Community with the economy of the United States is a striking reminder of the immense potential that lies within the community. The Western European economy has been growing at an average annual rate of 5 per cent since 1950, compared with a growth of 4 per cent per annum in the USA in the post-war period. Western Europe conducts one-third of the world's trade and constitutes the largest market for United States exports. Its 12 nations, now discussing integration into a free-trade area, constitute the most important competitor of the USA in world markets, exporting half as much again. The six EEC countries alone have a national gross product about 40 per cent of that of the United States.

The major conclusion drawn by the Chase Manhattan Bank is that United States business will have much at stake in the evolution of Western Europe's economy over the next fifteen years. "To the extent that this evolution strengthens Western Europe, both economically and politically," states the booklet, "it will prove to the advantage of all free nations." But the process will require many changes and adjustments outside of Europe, particularly by United States firms engaged in international business. The market for United States goods will grow, as will competition from Europe. American companies not now exporting to Europe or producing there may find it increasingly attractive as a production base. Those who are already exporting "may find it advantageous to set up subsidiaries in Europe, or to licence their product to European manufacturers." The message of the bank is clear enough: United States manufacturers must, in their own vital interests, come much closer to Western Europe than they have done so far.

Thoughtful Salesmanship

Salesmanship, or the lack of it, is without much doubt one of the main factors in British engineering's loss of ground in overseas markets. To be aware of this is a good thing, and the many courses and seminars being held to teach engineers how to sell could start a revival in this field, but there is a danger of our becoming obsessed by the idea that we cannot sell. For this reason, and because of the technical interest of the case, it is salutary to look back one or two generations and see how, what was then a very small engineering firm, did a superlative job of selling.

John Blake Limited, established in 1865 and now run by the third generation of the Blake family, make what they call Blake's Hydrams, that is, a range of hydraulic ram pumps. The skills are simply stated in a sub-title to the firm's name—"water engineers." The publicity places the accent on simplicity, low cost, no maintenance and utter reliability. A trade booklet, though old fashioned, in its appearance, is most attractively produced. It contains a description and simple illustration of the principle of the Hydram. A section is devoted to the conditions in which it can operate, how they can be assessed correctly, a statement of the data required by Blake to put forward a suitable pump, and the fact that Blake's application staff are "thoroughly experienced engineers" sent out to meet the world-be purchaser, or his agent, on the site for the proposed Hydram, "to confer with him as to a suitable way of placing it, take levels and measurements, and get such information as will enable us to send in a report and, if we consider the proposed scheme a good one, send a definite and formal tender for the work." The remaining 20 pages of the booklet contain examples of applications of the Hydram, with testimonials headed by one from the Duke of Marlborough and including a splendid list of aptly chosen remarks from users.

Perhaps the cleverest part of John Blake's sales technique was the despatch, as soon as an inquiry was received, of an outline scheme based on the facts about the location supplied by a 12 in to the mile Ordnance map. A full library of these maps of the United Kingdom is kept in the firm's offices in Accrington and photographs of the appropriate spot are sent out with the preliminary letter. Thus the potential customer realises from the outset that trouble has been taken to find out his own particular problem. All of this is good salesmanship, in the best tradition of the pioneers of British engineering.

Balancing Production and Sales

The importance of securing a balance as between production and sales was the main theme of a recent address by Mr. A. C. Hazel, managing director of Hurseal, to a conference on productivity held at Bristol University. Only by accurate forecasting of a 12 month's demand, he said, could a manufacturer ensure a steady and even load on the works during the 11 months production year. The distributor—or customer if the manufacturer trades directly—expects delivery off the shelf in a very wide range of engineering products with a short manufacturing cycle, such as the heating appliances and equipment produced by Hurseal. This meant that the manufacturer must make his sales forecasts sufficiently precise to enable him to make for stock with confidence (and maximum economy) during slack periods. Holding the right amount of stock is likely to be one of the main factors in profitability under severely competitive conditions.

Mr. Hazel pointed out that distributors or retailers often do not order in advance of their requirements. In fact there is a trend towards "last minute" ordering in many fields of engineering. This makes the manufacturer's task of balancing production with sales harder than it has been previously but is part and parcel of the new trading situation now developing. It is useless, and dangerous, to criticise the customer even when late ordering arises from inefficiency rather than deliberate policy. The whole process of forecasting sales is becoming the urgent concern of the engineering industry. So far it has not been very adequately performed and is one of the most common weaknesses in organisation and planning.

All-Out Selling

A one-day conference for managing directors and departmental managers is being arranged at the Royal Festival Hall on October 20 by the Incorporated Sales Mangers' Association under the title "Alerting Management for a Salesmanship Economy." This theme was determined by a forecast that industry will be under heavy pressure to expand its sales and particularly its exports.

Speakers will discuss the need for "vigorous salesmanship," not only among salesmen but in the board room and throughout a company. They will explain that only through increased sales consciousness can British industry maintain full employment and raise living standards. Lord Woolton, the president of the ISMA, will open the conference. Sir Nutcombe Hume, with Mr. C. A. S. Samuels, will speak on "The Managing Director's Personal Responsibility for the Company's Sales Dynamic"; Mr. Ronald Brech (economic adviser to Unilever) and Mr. R. Isdell-Carpenter (director of AEI-Hotpoint Limited) will present a paper entitled "The Market is What you Make it by Salesmanship"; and Mr. R. M. Melhuish (managing director of Fisons Pest Control) will present one on "The Effect of Sales Dynamic on Production Efficiency."

Salesmanship and Hospitality

From time to time stories reach us of inept and discourteous handling of overseas visitors. Perhaps the prize belongs to the American vice-president of a substantial engineering firm in the Great Lakes who was put up in a hotel at Balham and given a bus route to arrive at his licensee's office the following morning by 9 o'clock. But there are others and it is a subject upon which commercial staff of engineering concerns who have little experience of entertaining overseas visitors could usefully reflect.

A visitor came recently 3,000 miles from the Middle East to arrange a contract. He was not met at the airfield or station. The meeting over, he asked how to get back to his hotel and was told that if he walked to the end of the road he could get a bus to the door. Another instance of stupidity was provided by the contract managers who started looking at their watches at 5.20!

Most visitors from North America or the Continent of Europe prefer to be entertained in London's West End and do not much enjoy Reigate or Brighton or a riverside hotel in Bucks or Surrey in rainy weather. Nor do they much like being taken home unless it can be to a house large enough and with enough servants to enable them to feel at ease and not on top of their hosts and of their host's children. On the other hand visitors from the Middle East consider it a great honour, even in humble circumstances. There is a need for broad-mindedness and a sense of the appropriate which is often missing. Perhaps an elementary course on the entertainment of our friends from abroad would not be inappropriate.

Programme of Marketing Courses

An integrated programme of marketing courses has been designed by the Polytechnic's Department of Management Studies (309 Regent Street, London, W.1). Five courses have been arranged for the autumn term, beginning in October. Professor R. W. Clewett of the Northwestern University, Illinois, has joined the Polytechnic staff for one term and will take four of the five courses. He is a specialist in marketing organisation and technique in his own country and a consultant to a number of United States companies and to the European Productivity Agency. A marketing economist, Mr. Eric Shankleman, will be in charge of this section of the department's work and will lecture on "Marketing Principles." Professor Clewett's lectures will be on "Problems of Marketing Policy," "Case Examples in Industrial Marketing," "The Current American Marketing Scene," and "Trends in American Retailing." Three of the courses consist of six lectures, one of ten and another (on marketing principles) of fifteen. Fees range from £3 16*s*. 0*d*. to £9 9*s*. 0*d*.

Design

DESIGN OF SPIRAL BEVEL GEARS

With Cycloidal Tooth Length Curves

By A. K. Thomas, V.D.I., M.I.P.E.

Curved tooth bevel gears, generally termed spiral bevel gears, are produced by various methods. Depending on the principle of the machine on which the gears are to be cut, the tooth length curve or tooth trace in the pitch plane of the basic crown gear may be part of a circular arc,[1] an involute curve,[2] or a cycloid.[3]

In important bevel gear designs attention should be given to an accurate pre-determination, either graphical or mathematical, of the form of the tooth length curve produced on the gear cutting machine to be employed. This requirement will apply mainly to heavily loaded precision bevel gear drives in which the varying tooth thickness along the face width, as well as the change in spiral angle, and in conjunction with it the overlap ratio, must be taken into account.

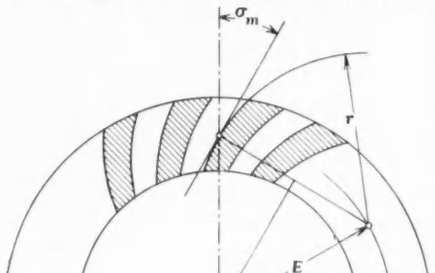


Fig. 1 Spiral bevel teeth with mean spiral angle σ_m.

Fig. 2 Spiral bevel teeth having zero spiral angle at mid point of face width.

The load carrying capacity of the teeth and axial thrust bearings in the gear drive depends largely on these design data.

In addition, another closely related item has to be considered, namely, localised tooth bedding. With some methods of generation a contact pattern reduced to a selected area in the lengthwise direction of the teeth is readily obtained, leaving the possibility of a slight variation in the position of contact to suit the requirements of different classes of users. It will be appreciated that a pre-selection of a certain contact area is only possible when the form of the tooth length curve is known, or can be accurately predetermined. In the case of circular arc-curved teeth,[1] the nature of the tooth length curve is clearly defined by its designation. With reference to the literature on gearing the method of determining the form of the tooth trace of involute-curved teeth[2] may also be assumed to be sufficiently well known. In this respect, however, there is a difference regarding the third type of spiral bevel gears, namely, those having a cycloidal tooth length curve.[3]

Generally speaking, little information is given in the literature of gearing regarding the calculation data or geometrical laws of the cycloid which must be known to enable a mathematical or graphical determination to be made of the cycloidal tooth trace produced by this particular method of generating spiral bevel gears. For this reason the graphical determination of the tooth length curves is often simplified by substituting a circular arc for the correct form (Figs. 1 and 2).

For many purposes such an approximation is quite sufficient, especially when cutting a large number of teeth employing single or double start cutter heads. In this case the deviation from the correct form measured over a length corresponding to the usual face width is generally very small. But if special cases are to be considered, as pointed out in the foregoing, the substitution of a circular arc cannot be regarded as satisfactory. With cutter heads having three or more starts, and a small virtual number of teeth T_v in the imaginary crown gear, viz., a small machine ratio of R_p, the difference between the simplified representation of the tooth trace and the correct curve can be quite considerable.

GENERATING PRINCIPLES OF CYCLOIDAL SPIRAL BEVEL GEARS

During the cutting process of this type of spiral bevel gear the work rotates continuously in timed relationship with a rotating cutter head (Figs. 4 and 5). In this cutter head are inserted a number of straight sided trapezoidal cutting tools distributed in pairs or "starts" round the centre of rotation. The ratio of rotation is determined by the number of starts in the cutter head, and the number of teeth in the gear to be cut. External cutters A and internal cutters B pass through the tooth gaps to be cut, following one another at a certain distance depending on the number of starts in the cutter head. By this action both the concave and the conjugate convex tooth curves are produced automatically. The tooth traces thus obtained are cycloidally curved, i.e., the tooth length curves are part sections of an extended epicycloid or of an extended hypocycloid. The latter will be produced only in exceptional circumstances.

With the cutting tools arranged symmetrically the teeth of mating gears cut with the same cutter radius and the same eccentricity of cutter head will theoretically mesh over the full length of their face width. This condition of bedding may be required in some cases, but in many instances it has been found advantageous to have a localised tooth contact pattern at a selected point on the face width, in order to eliminate errors arising from misalignment and shaft or bearing deflections under load, as well as manufacturing inaccuracies and hardening distortion of the teeth themselves.

Such a partial tooth bedding may be produced in various ways. Either by employing two separate cutter heads with different tool and eccentricity settings for the concave and convex flanks, or by a combination of a change of

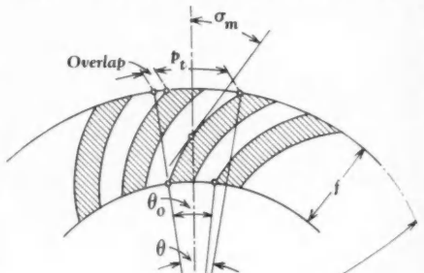


Fig. 3 Diagram showing overlap ratio.

rotation of the cutters and a change of eccentricity of the centre of rotation of the cutters. Both these methods are rather elaborate in their application, and a more practical solution is a cutter head provided with a mechanism which allows the external and internal cutters to rotate about two different centres adjustable to suit any required type of bedding. Also widely used are cutter heads in which a number of cutters are displaced relatively to produce a certain tooth bearing. It will be appreciated, however, that with such a simplified type of cutter head, i.e., with a fixed cutter setting, the selection of a contact pattern is usually restricted to the middle part of the face width.

The tooth profile itself is generated by an additional swivel action, i.e., by the feed movement of the cutter head axis about the axis of the generating drum or roll cradle in which the cutter head driving spindle is eccentrically mounted. The centre distance between cutter head and generator drum, i.e., the eccentricity can be adjusted to suit the various work diameters, and to obtain any required mean spiral angle.

The axis of the generator drum coincides with the axis of the imaginary crown gear. Both the axis of the crown gear and the axis of the bevel gear to be cut intersect in their common apex. The crown gear radius also represents the pitch cone distance of the work (Figs. 4 and 5).

Due to the traversing motion along the pitch

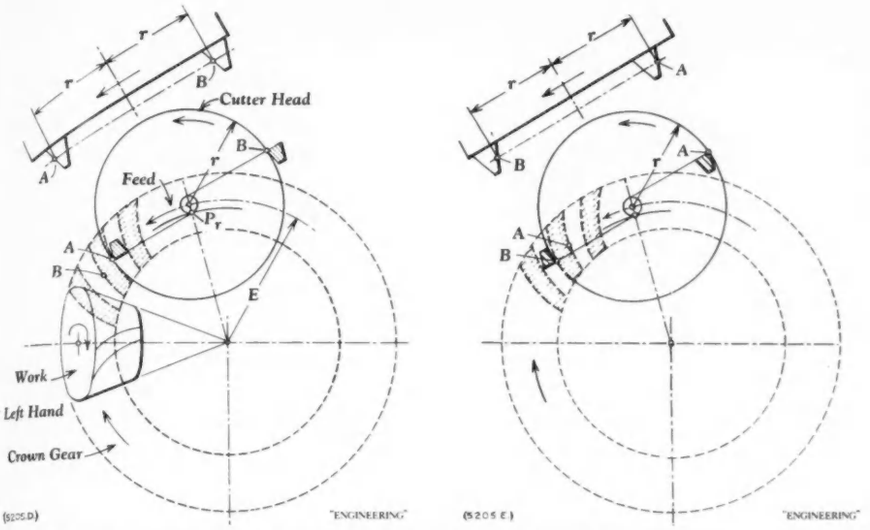


Fig. 4 Generating principle of left-hand spiral bevel teeth. In the diagram on the left the concave flank is being produced by a single-start cutter head. In the diagram on the right a similar cutter head is producing the convex flank.

plane of the crown gear the straight-sided trapezoidal cutters forming in their passage through the work the teeth of the crown gear, generate an involute tooth profile of constant depth. Hence, if two bevel gears mesh correctly with the same crown gear, they will themselves mesh together correctly.

The feed movement of the cutter head is compensated for by a differential in the gear train in the machine. It has, therefore, no influence on the form of the tooth length curve produced by the two rotary motions of cutter head and work spindle. But in addition to it, the radius of rotation of the cutters and the eccentricity have to be taken into account when determining the cycloidal tooth length curve.

The whole operating principle is a face-hobbing process with continuous indexing and roll generation. This generating method may also be compared with fly-cutting a worm wheel employing the tangential cutting principle. The only difference lies in the paths of traverse of tool and work, which are naturally different from those in the case of bevel gears.

It should be noted that in the following investigations, the tooth length curves on the work itself are not considered but their form in the pitch plane of the basic crown gear, i.e., in the developed pitch cone, is dealt with.

FORM OF TOOTH LENGTH CURVE AND SPIRAL ANGLE

Approximate Determination of Tooth Length Curve.—As previously stated, for spiral gears in general it will be satisfactory to obtain a graphical approximation of the tooth length curve by substituting a circular arc for the cycloidal form. The nominal or mean spiral angle σ_m, the amount of which, in conjunction with the face width, controls the overlap ratio, is determined by a given radius and eccentricity of the cutter head. Wherever possible the overlap ratio $\frac{\theta}{\theta_0}$ should be equal to or slightly greater than unity. The following guidance rule satisfies this requirement:

$$\tan \sigma_m \sim 1{\cdot}05 \;..\; 1{\cdot}3 \frac{p_t(C - f)}{f(C - f/2)}.$$

The mean spiral angle σ_m may lie between 30° and 45°. The smaller values are for gears for which great strength is of more importance than smooth running. Larger angles, with a maximum up to 45° are recommended for the quietest operation at high speeds. In such cases a greater axial thrust has to be taken into consideration. General recommended practice is:

Mean spiral angle	$\sigma_m = 30°$
Face width	$f = \frac{1}{3} C$
Cutter head radius	$r = \frac{5}{6} C$
Eccentricity	$E = r$

Under these conditions we have: $E = r = \frac{5}{6} C$ (Fig. 1). The overlap ratio may be calculated as follows:

$$\frac{\theta}{\theta_0} = \frac{C \pi \theta}{180° p_t}. \qquad \text{(Fig. 3)}$$

With bevel gears having zero-spiral angle at mid-point of face width,[4] then:

$$E = \tfrac{7}{8} C;\ r = \tfrac{5}{6} C. \qquad \text{(Fig. 2)}$$

It will be appreciated that the values for E and r given above may have to be changed to suit any particular requirements; for instance, to suit face widths smaller than $\frac{1}{3} C$, and restrictions in the settings of the cutter radius and eccentricity.

The foregoing guidance rules in respect of mean spiral angle and cutter settings apply to the standard cutting condition as described below. When employing the exceptional cutting method according to a later section, different spiral angles will be obtained with the same cutter settings.

GRAPHICAL DETERMINATION OF CURVE AND ANGLE

Standard Cutting Condition. Cutter Head and Crown Gear Rotate in Opposite Directions. (Figs. 4, 5, 6, 9 and 11.)

Definitions

Number of teeth in gear to be cut $= T_1(2)$.

Number of teeth in imaginary crown gear (virtual number of teeth):

Shaft angle $\Sigma = 90°$: $T_v = \sqrt{T_1^2 + T_2^2}$

Shaft angle $\Sigma \gtrless 90°$: $T_v = \dfrac{T_1(2)}{\sin \gamma_1(2)} = \dfrac{2C\pi}{p_t}$

Number of starts (pairs of cutters) in cutter head $= S$.

Machine ratio $= R_v = \dfrac{T_v}{S}$

Eccentricity (distance between cutter-head centre and crown-gear centre) $= E$.

Radius of rolling circle of cutter head $= r_c$.

Radius of rolling circle of crown gear (radius of directing circle) $= r_v$.

Imaginary pitch point between the two rolling circles $= P_r$.

Radius of rotation of cutters $= r$.

Cone distance $= C$.

Mean cone distance $= C_m$.

Face width $= f$.

Pitch angle $= \gamma_1(2)$.

Circular pitch $= p_t$.

The generating principle of the tooth length curves is best understood by visualising, between work and cutter head, an infinitely thin circular ring representing the pitch plane of the imaginary crown gear which rolls with them as they rotate. The ratios of rotation between these three elements, i.e., between cutter head, work and crown gear, are determined by the number of starts in the cutter head, the number of teeth in the gear to be cut and the number of teeth in the crown gear.

Considering the two rotary motions of cutter head and crown gear, we can further visualise two rolling circles which are dividing the centre distance E between cutter head and crown gear at the imaginary pitch point P_r into two lengths, corresponding to the ratio between the rolling circle radii r_c and r_v. When drawing the tooth length curve the rolling circle r_c of the cutter head is rolled upon the rolling circle r_v of the crown gear. Since for this purpose the latter circle must be assumed to be stationary it may also be termed the fixed or directing circle. Any point on the cutter head radius, in this case the cutting edge of the cutter, then describes in the pitch plane of the crown gear a looped or extended epicycloid. Its geometrical construction may be carried out as follows (Fig. 6).

Circular arcs with radii E and C_m are drawn from the crown gear centre. Two further circular arcs indicate the face width f. From any selected point O_c on the eccentricity circle of radius E the radius of rotation r of the cutters is drawn. The point of intersection between r

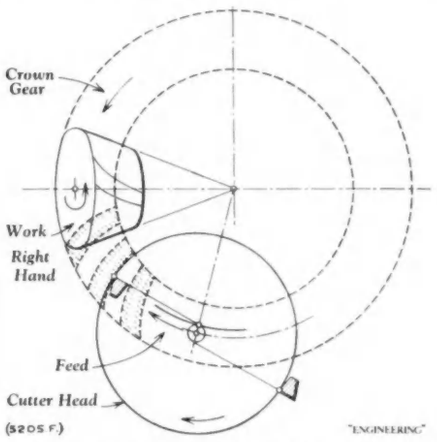


Fig. 5 Generating principle of a right-hand spiral bevel gear.

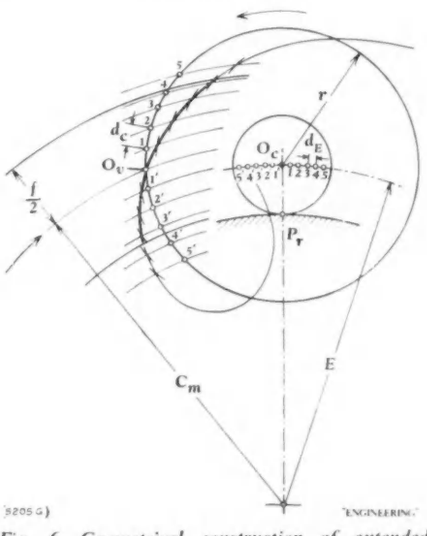


Fig. 6 Geometrical construction of extended epicycloid.

Continuing **Design**

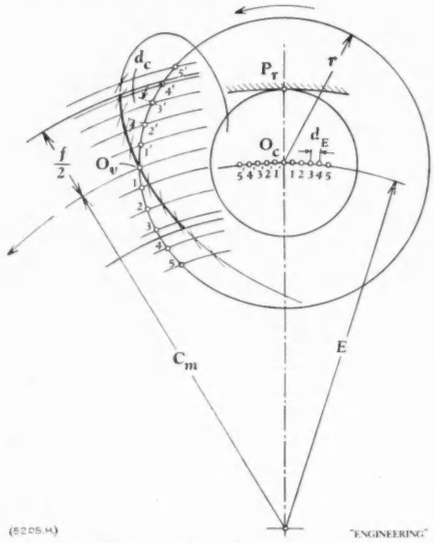


Fig. 7 Geometrical construction of extended hypocycloid.

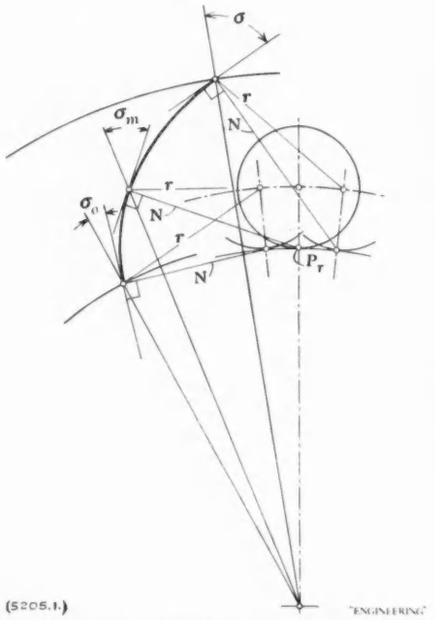


Fig. 8 Showing that the normal to the cycloidal curve at any point always passes through the pitch point of the two rolling circles.

and C_m is shown to be at O_v. Starting from the point O_v the circumference of the circle r described by the cutters is now divided above and below O_v in a convenient number of equal distances d_c. Through the points of division thus obtained auxiliary circles are drawn about the crown gear centre. Also on the eccentricity circle E starting on both sides from O_c the divisions d_E are marked, their distance depending on the magnitude of d_c. Then from the various points of division on E circular arcs with radius r are drawn. Their points of intersection with the auxiliary circles drawn about the crown gear centre mark the outline of an extended epicycloid. Although the distance d_c may be selected at will it must be chosen long enough to obtain values for the divisions d_E making a precise marking on the circle E still possible.

Between d_c and d_E the following relationship exists:

$$\frac{d_c}{d_E} = \frac{r}{E} R_v; \text{ or } d_E = \frac{E\, d_c}{r\, R_v}.$$

If the geometrical construction only of the tooth length curve is required it is not necessary for the rolling circle radii and the pitch point P_r to be determined. However, in order to determine the spiral angle at any point along the face width, the position of the pitch point must be known.

When using the graphical method shown in Figs. 6 and 8, the spiral angle can easily be found by drawing a straight line from the point concerned on the tooth curve to the pitch point P_r. The perpendicular to this straight line representing a tangent to the cycloidal curve at that point on the face width, and the radial line to the crown gear centre includes the required spiral angle σ_m. Since, according to its geometry the normal to the cycloidal curve at any point passes through the tangent point of the rolling circles, this graphical method gives rapid and sufficiently accurate results in finding the various spiral angles along the face width. The radii of the rolling circles are given by:

$$r_c = \frac{E}{R_v + 1}, \; r_v = \frac{E}{\frac{1}{R_v} + 1} = E - r_c.$$

It will be appreciated that in many instances the cycloidal form of the tooth length curve differs very little from a circular arc with radius drawn from the pitch point P_r. (Figs. 6 and 8.)

This method of substituting a circular arc with its centre at the pitch point for the correct tooth length curve is preferable to the rough approximation shown in Figs. 1 and 2. Furthermore, since the value of the cutter head rolling circle is usually required as a dimension for the cutter setting gauge, no additional work is really involved in determining the pitch point. However, with a small machine ratio, viz., with cutter heads having more than two starts in conjunction with a small number of teeth in the work, it is preferable to carry out the geometrical construction of the cycloidal curve as described in the foregoing.

Exceptional cutting conditions. Cutter head and crown gear rotate in the same direction. (Figs. 7 and 10.)

With this method of cutting the rolling circle r_c of the cutter head rolls *inside* the stationary assumed rolling circle r_v, i.e., the directing circle of the crown gear. Under these conditions a point on the circumference of the circle described by the cutters traces out the path of an extended hypocycloid. The general construction of such a curve is very close to that for the epicycloid.

The radii r_c and r_v are in this case given by:

$$r_c = \frac{E}{R_v - 1}, \; r_v = \frac{E}{1 - \frac{1}{R_v}} = E + r_c.$$

As a hypocycloidal tooth trace generally shows only a slight curvature in many cases practically

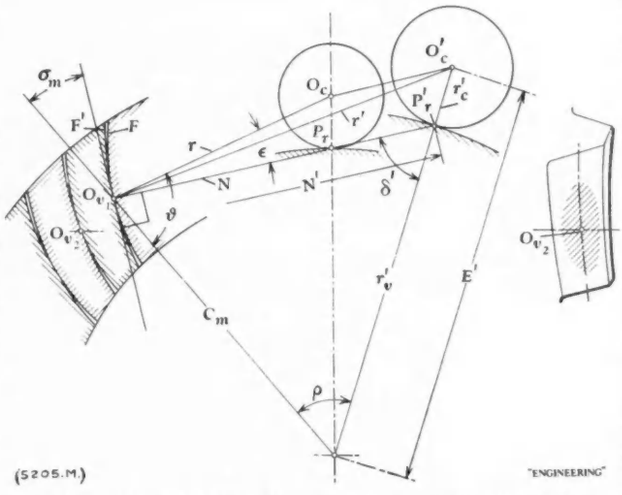


Fig. 11 Epicycloidal tooth length curves produced with different cutter head radii for the concave and convex flanks. Ov_2 = centre of contact area between the teeth.

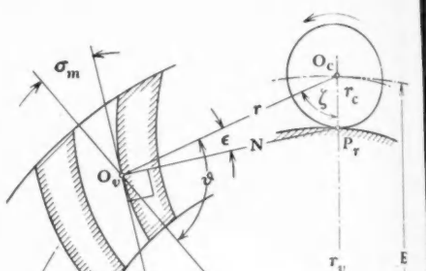


Fig. 9 Geometry of the epicycloidal tooth length curve.

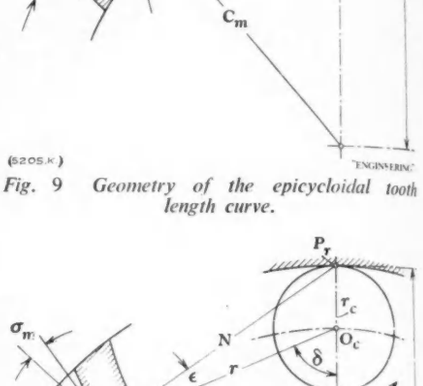


Fig. 10 Geometry of the hypocycloidal tooth length curve.

straight teeth can be obtained by this method of cutting.

MATHEMATICAL DETERMINATION OF SPIRAL ANGLE

Standard cutting condition. Extended epicycloid. (Fig. 9.)

$$\sigma_m = 90^\circ + \epsilon - \vartheta$$

$$\cos\vartheta = \frac{r^2 + C_m^2 - E^2}{2\,r\,C_m}; \quad \cos\zeta = \frac{r^2 + E^2 - C_m^2}{2\,E\,r}$$

$$N^2 = (r\cos\zeta - r_c)^2 + C_m^2 - (E - r\cos\zeta)^2$$

$$\cos\epsilon = \frac{r^2 + N^2 - r_c^2}{2\,r\,N}.$$

Exceptional cutting condition. Extended hypo-cycloid. (Fig. 10.)

$$\sigma_m = 90^\circ - \vartheta - \epsilon$$

$$\cos\vartheta = \frac{r^2 + C_m^2 - E^2}{2\,r\,C_m}$$

$$\cos\delta = \frac{r^2 + E^2 - C_m^2}{2\,E\,r}$$

$$N^2 = (r_c + r\cos\delta)^2 + C_m^2 - (E - r\cos\delta)^2$$

$$\cos\epsilon = \frac{r^2 + N^2 - r_c^2}{2\,r\,N}.$$

TEETH WITH LOCALISED BEDDING

The cutter head rotating about its centre O_c, with the cutters set at a radius r produces equal tooth length curvatures for both the convex and concave flanks (see Figs. 9 and 11). Theoretically full-length bedding along the tooth curve

will thus be obtained. If a selected bearing area in longitudinal direction of the teeth is required the convex and concave flanks have each to be produced with a different curvature. This may be achieved by causing the cutters for the concave flanks, set at a slightly larger radius than those for the convex flanks, to rotate about the centre O'_c at the extended eccentricity E′. The centre distance $O_c - O'_c$ then represents a measure for the difference of curvature of the two engaging flanks: the greater the difference the shorter the tooth bearing becomes.

The position of the contact area of teeth with localised bedding is determined by the direction of the common normal N′ to the selected point on the face width. Since the normal N′ passes through both pitch points P_r and P'_r to which the line joining O_c and O'_c is parallel the position of the new cutter head centre O'_c is clearly fixed by the chosen eccentricity E′.

The ratio between the rolling circle radii r'_c and r'_v for the concave flank F′ is equal to the ratio between the rolling circle radii r_c and r_v for the convex flank F. Hence $\frac{r_c}{r_v} = \frac{r'_c}{r'_v}$. The magnitude of the radius of rotation of the cutters r' for the concave flank F′, depending on the selected eccentricity E′, may be derived from the geometry of Figs. 9 and 11, and using the symbols there indicated:

$$\sin \delta' = \frac{C_m \sin (\vartheta - \epsilon)}{r'_v},$$

$$\rho = 180^\circ - \delta' - \vartheta + \epsilon,$$

$$N' = \frac{r'_v}{\sin (\vartheta - \epsilon)} \sin \rho,$$

$$r' = \sqrt{(N' \cos \delta' + r'_c)^2 + C_m{}^2 - (r'_v - N' \cos \delta')^2}.$$

With Fig. 11 and the foregoing equations it is thus possible to predetermine graphically or by calculation the position of the contact area of spiral bevel gears having cycloidal tooth length curves.

For producing a specified bearing along the teeth of this type of spiral bevel gears various ways and methods are mentioned in the section dealing with generating principles.

Theoretically, the slightest difference between the cutter head radii r and r', for the convex and concave flanks respectively, would result in point contact between the teeth. In practice, however, the tooth contact pattern spreads over an area the length of which depends on the difference between r and r'. To determine this difference experiment is usually required, taking into account hardening distortion, gear mounting and load conditions.

REFERENCES

[1] "*Gleason*" *spiral bevel gear generator.* This machine embodies the principles of step by step indexing and roll generation of the tooth profiles. The cutter is of the circular face-mill type producing tooth length curves that are circular arcs.

[2] "*Klingelnberg*" *spiral bevel gear hobbing machine.* This employs a conical shaped hob which produces involute tooth length curves in a continuous generating process completing the profile of all the teeth in a single generating roll motion.

[3] *Spiral bevel gear generators operating on the principle produced and developed by Dr. Benedetto Mammano of Milan* (Craven, Fiat, Oerlikon). These machines use a single- or multiple-start cutter head with inserted trapezoidal tools. The continuous rotation of the cutter head and gear blank, i.e., continuous indexing, generates a tooth length curve of cycloidal form. A single generating roll motion completes the work at one pass.

[4] Trade-marked name: "Spivoid" teeth (Craven machine) "Zerol" teeth (Gleason machine).

HEAT AND THE ENGINEER

Concluded from page 384
September 19

By Professor O. A. Saunders, F.R.S.

*Presidential Address to Section G of the British Association**

The first half of Professor Saunder's Address, published last week, dealt with heat and heat transfer in general terms. The second half (which is slightly abridged here) is devoted to some practical applications involving heat flow.

REGENERATORS

The regenerator is one of the oldest forms of heat exchanger, large brickwork regenerators beneath steel melting and other types of furnaces being very common from the earliest days of furnaces, for the purposes of preheating air or gas to obtain higher flame temperatures and to recover waste heat. These regenerators also had the advantage that by the use of ceramics rather than metal, as in recuperators, high working temperatures were possible before the discovery of heat-resisting metal alloys.

The regenerator is, however, apart from the use of ceramics, fundamentally a very attractive principle of heat exchange because it uses the same passage for alternate flow of hot gas and cold air, instead of two passages separated by a dividing wall as in the recuperator. This eliminates the mechanical problem of separately sealing off each individual tube as in the tubular recuperator, and allows a better shape of flow passage for both fluids instead of, for example, the tortuous flow across baffled tube banks of a tubular recuperator. Also there is the possibility with regenerators of making the individual flow passages so small that the flow is laminar, and thereby reducing the ratio of friction pressure loss to heat transfer, which would be impossible with tubular recuperators in which tubes smaller than ¼ in have not been contemplated for any large-scale exchangers because of the enormous problem of sealing tens of thousands of tubes into endplates. The thermal recovery of a regenerator can also be raised to very high values, over 90 per cent, by so arranging the temperature distribution within the solid that it resembles that in a counterflow recuperator, and by choosing the periodic time between reversals small enough for the solid temperature to fluctuate only slightly.

These ideas on regenerators, which represent a new departure from the old massive brickwork regenerators of the steelworks, were first pointed out by Ritz after the war, but despite the advantages just described, the use of regenerators in industry has not yet extended much because of practical difficulties in finding a satisfactory mechanical arrangement. Two methods are possible: either to use stationary solid matrices with reversing valves, or to use a form of continuously rotating matrix such as a disc or cylinder, part of which is situated in the hot stream and part in the cold, so that the rotating matrix passes from one to the other. The former arrangement is clumsy, and the latter involves some form of rubbing or rolling seal. For applications where compactness is essential, such as the vehicle gas-turbine, the rotating regenerator is very attractive, but the problem of developing a seal which is effective with pressure differences of two or more atmospheres and does not wear unduly, has not yet been solved. The whole future of the gas-turbine for motor vehicles, and possibly other mobile applications, would be transformed by the development of a satisfactory regenerative heat exchanger, and although there are rumours of some success in the United States by General Motors, nothing has yet emerged.

HIGH-SPEED HEAT TRANSFER AND MISSILE HEATING

The principles of aerodynamic heating are now fairly well understood. The dissipation of energy by viscous action in the rapidly shearing boundary-layer air develops heat which is removed into the main air-stream by conduction or eddy diffusion, but the two processes are so related that an equilibrium temperature is reached which, if the surface is unheated, is termed the adiabatic wall temperature and exceeds the main stream temperature by an amount depending on the Mach and Prandtl numbers of the stream. This excess temperature rises with the square of the Mach number, and at M = 5 reaches about 1,100° C for air at sea-level temperature. Aircraft flying at supersonic speeds, and still more missiles, therefore reach high temperatures even in the upper colder layers of the atmosphere, and metal models of conical missile heads have melted in a wind tunnel at M = 6·9 after only about 20 seconds. Even if the surface does not melt, except when the duration of high-speed flight is short, the penetration of heat into the structure is unacceptable, and even for short durations severe thermal stresses may be caused.

Various ingenious means have been proposed to overcome these difficulties. For continuous operation a source of cold is needed and in an aircraft this means either a refrigeration plant or using the cold capacity of the fuel, which is substantial especially for supersonic transport aircraft which requires large jet engines. The attractions of using a cold fuel such as liquid hydrogen are considerable since most of the sensible "cold" is in the form of specific heat rather than latent heat. The distribution of the "cold" throughout the aircraft structure and cabin is, however, no small problem. Another method, particularly for missiles, is to allow the metal surface, or some material coating it, to sublime into the air, thus abstracting latent heat at the surface. For all these purposes the designer needs to know heat-transfer coefficients at very high Mach numbers, and although there is good evidence that the heat transfer is proportional to the difference between the surface wall temperature and the equilibrium adiabatic wall temperature up to Mach numbers of 4 or 5, there is still uncertainty concerning the heat-transfer coefficients at very high Mach numbers. One difficulty is that there is evidence that the condition of flow in the boundary layer may be affected by the Mach number and also by the abstraction of heat, though this probably means a lower heat transfer coefficient than would otherwise be expected.

In connection with aircraft and aero engines I encountered an interesting heat-transfer problem in the early days of the last war, when I was asked by Sir Henry Tizard to consider means of injecting oxygen into Merlin aero engines to restore the loss of power above the rated altitude, above which the supercharger is unable to maintain the maximum supercharge pressure, the aim being to raise the maximum ceiling to which fighter aircraft could climb, then about 36,000 ft. It was immediately evident that the oxygen had to be carried as liquid, and a system was devised

* Address delivered at Glasgow on the 29 August 1958.

Continuing Design

for injecting liquid oxygen into the air intake of the engine. A serious difficulty, however, was that on turning on the liquid oxygen from the supply tank, the 14 ft pipe leading to the injection nozzle became vapour locked and a minute or so elapsed before the steady supply could be established, which was useless from the pilot's point of view.

Insulation of the pipe was no help. In the end a double-wall self-refrigerating pipe was devised with a number of small holes in the wall of the inner tube through which the liquid oxygen escaped into the annular space between the two tubes and cooled it mainly by evaporation. By suitably arranging the disposition of the small holes, the inner tube could be made to cool itself down to the boiling point rapidly enough for the liquid oxygen flow in the inner tube to become regular and full in a few seconds after turning on. Eventually the appliance was installed in a fighter aircraft and raised its ceiling from 36,000 ft to 38,000 ft, also improving the mean rate of climb between 30,000 ft to 35,000 ft from 650 ft. a minute to 900 ft a minute with a total duration of about 15 minutes. But for the arrival of the gas-turbine aircraft engines the device might well have had a much wider use.

DROPWISE CONDENSATION

For a long time it has been known that the heat transfer between a vapour and a surface upon which it is condensing, is much greater when the surface is not fully wetted and the vapour condenses as drops rather than as a continuous film. This conclusion was based on a simple measurement of steam condensing on a small surface, and coefficients of tens of thousands in British Units have been observed, compared with values of the order 1,000 for film condensation. Incidentally the precise physical mechanism of dropwise condensation is still uncertain, and we do not really know why it gives such high values. Although the absence of the liquid film through which the heat of condensation must pass to the surface obviously reduces the resistance to heat transfer, the proportion of the surface in contact with the drops is not large, and the drops themselves are not so small as to offer no resistance to heat conduction. It is disputed whether or not condensation can take place on the bare surface between the drops, and theories have been suggested which involve rapid turbulence in the vapour close to the drop surface caused by movement of the drop surface due to surface tension variation with temperature. Whatever the explanation may be there is no doubt of the fact, and the question of practical application has caused much interest especially recently.

The difficulty of promoting and maintaining the dropwise condensation has been substantially overcome in the case of steam condensers by the development at the Mechanical Engineering Research Laboratory of chemical additives of the mercaptan type, very small quantities of which are found to have the desired effect for quite long periods.

EFFUSION COOLING

The cooling of a surface by forcing gas or liquid coolant through pores or slits or holes was first mentioned by Duwez. The main cooling effect arises from the insulating layer of cool fluid interposed between hot stream and the surface, though heat is also removed from the wall by the coolant direct. The effect is increased if the fluid is liquid and vaporises on emerging from the wall surface. The theory of this process has been worked out for continuous injection, but in practice only the use of porous walls gives a continuous film, the effects of injection from slots or holes being localised. Porous injection also tends to be wasteful of coolant in the downstream parts unless the distribution of injected flow can be made non-uniform by controlling the porosity or by some other means. The most obvious applications of effusion cooling are to gas-turbine blades and combustion chambers, rocket chambers, missiles, and other cases where the protecting of the surface from a hot gas enables a cheaper material or high gas temperature to be used, but it is essential to have a supply of coolant and one criterion by which effusion cooling is judged against other methods is the amount of coolant needed.

It is now generally agreed that, for most of the applications mentioned, effusion cooling through porous walls such as sintered metals is more economical of cooling air than other methods such as internal blade air passages, especially if the distribution of coolant can be efficiently arranged, but the main reason why the method has not been used much so far is the decreased mechanical strength, both tensile and shock, of sintered metals and ceramics compared with metallic alloys. There is no fundamental reason why sintered metal should not have comparable mechanical strength to metals, and more will probably be heard of these methods in the future, perhaps as a means of cooling local hot spots rather than of cooling large areas.

RADIATION FROM LUMINOUS FURNACE FLAMES

The luminous flame, from which heat is radiated by small carbon particles produced by heating in a local deficiency of oxygen, is widely used in boilers and industrial furnaces, especially open-hearth steel-melting furnaces. The calculation of the heat radiated from such flames is extremely difficult because we do not know the number and size of the carbon particles at each position along the flame. The design of furnaces is often extremely critical, and a better control of flame radiation might well save a lot of money both in fuel consumption and in initial and maintenance cost. In the open-hearth steel-melting furnace particularly, the refractory roof has to be renewed frequently, and anything which can be done to lengthen its life while maintaining or even improving the time of melting is of considerable economic value. Since radiation processes do not scale down directly, measurements must be made on flames of comparable size to actual furnace flames.

The work of the International Flame Research Organisation at Ijmuiden in Holland, has done much towards the solution of these problems by systematic measurements of radiating powers, temperatures, emissivities, etc., of flames from a variety of burners, conditions of air preheat, etc., with gaseous liquid, and solid fuels. The results so far indicate that for oil-fuel diffusion flames, that is oil flames in which the majority of the combustion air is entrained by the flame jet from its surroundings, the flame length is mainly determined by aerodynamic variables and particularly by the momentum of the inflowing jet, and may be studied by model techniques. The radiation distribution over the flame length is dependent mainly on the carbon-hydrogen ratio of the fuel and the initial rate of mixing of air and fuel at the burner. Near the burner the emissivity is high, often approaching unity, decreasing as the carbon burns away along the flame, but since the temperature tends to rise along the flame the actual radiation does not vary greatly along the flame length. Several results of practical value have emerged from these investigations, including the importance of the momentum of the burner jet and the effect of adding pitch creosote to flames of low radiation such as coke oven gas flames, in order to increase their radiating power.

COOLING TURBO-ALTERNATORS

The cooling of the windings of a turbo-alternator is of great importance especially in view of the uprating of output of a given size which has been demanded in recent years. Recently, direct cooling of both stator and rotor coils using hydrogen at pressures up to 30 lb per sq. in has been developed, in some cases the coolant passing through the conductors themselves which are of tubular form. The reduction in material weight per kilowatt with the consequential increase in maximum rating has been sensational, especially with direct conductor cooling and using high-pressure hydrogen. These improvements have opened up a new range of unit sizes from 200 MW up to 350 MW. It may be said that by far the biggest advance in turbo-alternator design during recent years has come from improved heat transfer.

LIQUID METALS

The use of liquid metals for heat transfer has been brought to the forefront by nuclear reactor developments, since their high thermal conductivity makes them suitable for applications where very high heat transfer rates are required, as in the fast neutron reactor. Moreover, in sodium and sodium-potassium eutectic alloy particularly, we have substances which do not capture neutrons wastefully and are therefore acceptable for reactors.

Prior to the nuclear application the only liquid metal used was mercury which has the disadvantage of toxicity. Heat-transfer coefficients for liquid metals have now been extensively measured, but there is still some uncertainty in interpreting results which may be connected with the effects of thermal conduction in the direction of flow, which is negligible in non-metallic liquids. Liquid metals will probably be more widely used for heat transference in many industrial applications in the future, such for example as in steam reheating in power plant where they would enable the steam to be heated in heat exchangers close to the turbines. It is to be remembered, however, that liquid metals have relatively low specific heats compared to other liquids, which means that the weight of fluid necessary for a given heat removal may be high. The high temperature-drops across the thickness of the walls of the tubes carrying liquid metal coolant may also become a critical factor, reaching as much as 500° F in 0·02 in thickness of stainless-steel tube wall, for a flux of 3 million B.t.u. per sq. ft per hr.

CONCLUSIONS

In this address I have mentioned only a few of the many kinds of heat transfer problems. It seems that with the coming of new industries such as electronic, aircraft engineering, nuclear and chemical engineering, quite new kinds of heat transfer problems arise, or at any rate unexpected developments of old problems, with the result that the scientists and engineers are trying to solve new problems and consolidate the background of the subject at the same time. However, an immense amount of theoretical and experimental effort is now being put into heat-transfer research today, especially in the United States, and the recent words of H. L. Dryden, director of the National Advisory Committee for Aeronautics, may well be quoted:

Creative research, inventive development, inspired design and novel construction in the field of heat transfer—all must be accelerated on a broad front to keep pace with the needs of modern technology. Nuclear reactors, rocket engines, high-speed ballistic missiles re-entering the atmosphere, and certain types of chemical engineering equipment encounter extreme conditions of temperature and rate of heat transfer, challenging scientists and engineers to explore new problems and ranges of parameters.

Theoretical methods have greatly contributed to advancing our knowledge in the last quarter of a century, and will continue to do so, but I should like to conclude by making a plea for more experimental work. This can be of two kinds. First, we need careful experiments under controlled conditions, to evaluate physical properties and the experimental constants of phenomena such as turbulent convection. Secondly, we need more experimental observation of what is happening in actual appliances. In heat transfer experimental measurements are not easy, and there are plenty of opportunities awaiting the young research physicist and engineer.

Book Reviews

PICTURES OF STRAIN

A Treatise on Photoelasticity. By E. G. COKER and L. N. G. FILON. Second Edition. Revised by H. T. JESSOP. *Cambridge University Press, Bentley House, 200 Euston Road, London, N.W.1.* (70*s*.)

It is now close on half a century since Coker and Filon began to publish the results of researches into the pictorial representation of strain patterns obtained by the nowadays widely-known method of passing polarised light through loaded models made of transparent plastic material. More than any other investigators of photoelasticity, they deserve the credit of having created a new branch of applied engineering science that has since grown to be universally acknowledged as one of the most valuable practical means of stress analysis. After twenty years spent in improving their experimental techniques and using them to examine problems of stress distribution in mechanical and structural engineering components, they collaborated in presenting a comprehensive and authoritative treatise that was at once acclaimed, and has since remained, the classsical standard work on the theory and practice of photoelasticity.

This book has been out of print for several years, and the preparation of a second edition has been achieved with conspicuous success by Mr. H. T. Jessop who, as senior lecturer in photoelasticity at University College, London, is not only in the direct line of descent from Coker and Filon, but is a well known authority in his own right. He is completely aware, therefore, of the very considerable advances in photoelastic technology that have taken place since the first edition was published in 1931, and of the occasional inaccuracies in the numerical results of stress problems investigated with apparatus that now belongs to the history of the subject. Again some of Coker and Filon's original studies of stresses in specific components prompted design changes that have since been so generally adopted, for reasons that are now common engineering knowledge, as to give the impression that the authors' treatment as a whole may be out-dated. Such is emphatically not the case. The developments of recent years, while admittedly great and valuable, have in no way impaired the validity of the basic optical and elastic theory that forms the most important part of Coker and Filon's work. Indeed, the advanced photoelastic research now being directed to problems of three-dimensional and plastic strain emphasises the inadequacy of superficial theoretical knowledge and the need for the thorough, fundamental approach demonstrated by Coker and Filon.

Wisely, therefore, Mr. Jessop has not attempted either to make extensive alterations to the text or to write the additional volume that a completely up-to-date handbook would demand. The second edition is substantially the same as the first. A few misprints and two minor errors have now been corrected, but the only obvious difference is the substitution of half-tone prints for the coloured fringe pictures of the original—a change wholly justified by the modern use of monochromatic light in experimental photoelasticity, and calling for only trifling modifications to the relevant text. The general arrangement and sequence of subject matter remain unaltered. The first three chapters present, in turn, the physical and mathematical theory of general optics, elasticity, and artificial double-refraction appropriate to the photoelastic study of mechanical strain. In three further chapters mathematical and photoelastic methods are used to analyse typical problems of stress distribution as it is affected by the shape of boundaries, the presence of holes or cracks, and the proportions and methods of loading of beams. A number of the authors' photoelastic studies of specific problems arising in materials-testing practice, and in the design of typical components of machines and structures, are described and discussed in the concluding chapters. A most valuable addition to the original text is a Reviser's Introduction—a quite masterly essay in which Mr. Jessop outlines the development of experimental photoelasticity to its present state, paying considerable attention to improvements in photoelastic materials, as well as in the apparatus and techniques, that are now employed for exploring strain distributions in three dimensions. The abundant bibliography on which the essay is based covers every notable development in photoelasticity during the past 25 years.

The book as a whole evokes comment along two lines. Regarded as a technical product this handsome volume with its clear, well-arranged text, illustrations and mathematical typography, reflects the utmost credit on Mr. Jessop for his care in revision, and on its publishers whose superlative standard of craftsmanship is, as usual, beyond criticism. Somewhat less simple to express is the opinion that this is primarily a treatise for serious students of graduate standing, having already some knowledge of optics and elasticity, and unlikely to be deterred by whole pages of somewhat formidable mathematics. Coker and Filon imply unmistakably that the correct practice of photoelastic stress analysis demands a degree of specialisation that can best be attained, and retained, in universities, technological institutes and large engineering research establishments, probably most of which, both here and abroad, now possess well equipped photoelastic laboratories. In the more numerous development laboratories of small engineering firms the expense of precise photoelastic apparatus, and the time needed by highly qualified staff to use it for quantitative stress investigations, are less easily justified. Many such firms, of course, occasionally improvise a photoelastic bench to assist in the design of a new component or indicate a weakness that has led to a service failure; and for either purpose a brief, qualitative experiment can be both rewarding and convincing. It will often be the case that approximate observations of this sort can be greatly enhanced in value by reference to the full analysis, by Coker and Filon, of a similar problem. Apart, moreover, from the photoelastic aspect, the results of these analyses embody a great deal of information that is still imperfectly appreciated by many designers. The publication of this new edition is thus assured of a cordial welcome over an increasingly wide range of engineering practice.

TRADE PUBLICATIONS

Copies of any of the following trade publications are obtainable from the addresses given, though distribution is sometimes restricted.

Air Filters. VOKES LTD., Henley Park, Guildford, Surrey. Special-purpose filters for atomic energy, biological, pharmaceutical, photographic, and similar high efficiency applications; "absolute" panel filters, box-type canister filters, composite filters for air conditioning, glove-box filter with fume and vapour removal unit, reverse-flow multiple-cyclone units. Illustrated descriptive brochure. (This paragraph corrects one published in issue of 8 August.)

Machine Units. K. S. PAUL LIMITED, Great Western Trading Estate, Park Royal Road, London, N.W.10. Otnima standard units for building into special machine tools; drill heads, spindles, feeders facers and tables. Leaflet.

Air-Operated Tools. THE CLIMAX ROCK DRILL AND ENGINEERING WORKS LIMITED, Carn Brea, Redruth, Cornwall. Air-operated Maxam machine tools; drill heads, feeds, tapping heads and special purpose machinery. Brochure.

Precision Finishing. A. A. JONES AND SHIPMAN Limited, Narborough Road South, Leicester. Issue No. 15 of "Machine Tools" deals with precision grinding and surface finishing.

On the Shelf

By Frank H. Smith

The Royal Institution *Proceedings* will, in future, be issued three times a year at 8*s* 6*d* per number; and from January 1959, at an annual subscription of 21*s*.

Describing itself as the British aviation national monthly, *Popular Aviation Review* No. 1 is dated July 1958. It runs to eight pages, is "newspaper style" and has banner headlines. Ten shillings per annum from Brackens, Dormans Park, near East Grinstead, and orders made out to the new paper.

I expect many of my readers are aware that in the States there is quite a rash of journals, digests and what have you beamed at the Big Business Executive. They usually either tell him what he should read or digest it for him. They are full of figures and comparative statistics.

It seems that the editor of one of the advisory types is an avid reader of ENGINEERING, since Mr. Donald T. Clark, of *E the Executive: a guide to reading for top management* (that's how the tasteful cover reads) has sent me a copy of Volume 2, No. 2, of his journal, which emanates from Baker Library, Harvard University Graduate School of Business Administration. This journal does in a superlative way what I try to do in this column. Books, such as *The American Stockholder*, *Capitalist Economy and Business Civilisation*, *Madison Avenue U.S.A.* and articles such as "Education, Profession and Public Affairs" and "Maginot Line Thinking for High Management" are reviewed and the centre pages are "This May Interest You," by the editor. I was flattered to read in the last that he highlights an article in *The Lamp* on "How to Read an Annual Report." I wrote about this myself a few months ago but I cannot remember whether it appeared in this column or had to make room for something else (this happens to me when I churn out too much). On the accompanying editor's slip Mr. Clark writes "will you please tell Mr. Ward that we enjoyed his article. Excellent!" Incidentally, this journal costs only 5 dollars a year from *The Executive*, Room 324, Baker Library, Soldiers Field, Boston 63, Mass.

A short while ago I commented that in America they seem to have standardised the size of programmes for forthcoming conferences at about 8½ in by 4 in. The fever is spreading and Cox and Cox, Management Consultants, 333 North Michigan Avenue, Chicago, use a folder of this size to publicise their latest management report ("on a very hot subject") entitled "Numerically Controlled Machine Tools" and costing a mere 25 dol. "Numerical control is the operation of general-purpose machine tools from stored, preprogrammed, reusable electronic instructions (tape, punched cards, etc.)." It seems that Cox and Cox are "sold" on the idea and are determined that a lot of other people should go the same way—at 25 dol a helping.

The Library Association, Chaucer House, Malet Place, London, W.C.1, have published a "Readers' Guide to Mechanical Engineering." Although they are the publishers one is, apparently, expected to buy from the County Librarian, East Fergus Place, Kirkaldy, Fife, he being the Honorary Publications Secretary. All very complicated. I do not propose to wade through the list in the hope of finding an obvious omission. It is 34 pages of close, small type and should form an excellent guide to anybody wanting to start a library in any or all of the subject headings ranging from General Works, through most, if not all, of the main branches of mechanical engineering. At 1*s*. plus 2*d*. postage you cannot go far wrong.

Penguin (whom I suppose one thinks of as the original paperbacks) have issued their August list (ready 28th) and it includes Arthur C. Clarke's *The Exploration of Space*.

EXHIBITIONS AND CONFERENCES

This list, in chronological order, appears in the last issue of each month. Events noticed for the first time and alterations of dates, places, etc., are indicated by an asterisk (*). For details of events not included below, reference should be made to ENGINEERING, 25 *July, page* 125, *and* 29 *August, page* 276. *Organisers are invited to send particulars of coming events to the Editor.*

Cattle and Agricultural Machinery Fair, National.—In October, at Quinta Normal. Apply to the British Chamber of Commerce, Casilla 536, Santiago.

***National Society for Clean Air, 25th Annual Conference.**—Wed., 1 Oct., to Fri., 3 Oct., at Llandudno. *Offices:* Palace Chambers, Bridge Street, London, S.W.1. Tel TRAfalgar 6838.

Kenya Royal Show.—Wed., 1 Oct., to Sat., 4 Oct., in Nairobi. Organised by the Royal Agricultural Society of Kenya, P.O. Box 30176, Nairobi, Kenya.

Motor and Cycle Show, 45th International.—Thurs., 2 Oct., to Sun., 12 Oct., in Paris. *Agent:* Mr. R. C. Liebman, 178 Fleet Street, London, E.C.4. Tel. CITy 5889.

Pre-Packing of Fresh Fruit and Vegetables, International Exhibition of.—Tues., 7 Oct., to Thurs., 9 Oct., at the Royal Horticultural Society's new hall, Greycoat Street, London, S.W.1. Organised by the Produce Pre-Packaging Development Association, Agriculture House, Knightsbridge, London, S.W.1. Tel. BELgravia 6431.

Future of Structural Engineering.—Tues., 7 Oct., to Fri., 10 Oct., fiftieth anniversary conference of the Institution of Structural Engineers, to be held at its headquarters, 11 Upper Belgrave Street, London, S.W.1. Tel. SLOane 7128.

Communications, International Meeting on.—Tues., 7 Oct., to Sun., 12 Oct., at the Palazzo San Giorgio, Genoa. Apply to Civico Istituto Colombiano, Genoa, Italy.

Radio Engineers' Canadian Convention and Exposition.—Wed., 8 Oct., to Fri., 10 Oct., in the Exhibition Park, Toronto. Organised by the Institute of Radio Engineers, 1819 Yonge Street, Toronto 7, Canada.

***Accounting Aids to Productivity, National Conference.**—Wed., 8 Oct., to Sat., 11 Oct., at the Washington Hotel, Curzon Street, London, W.1. Organised by the Society of Commercial Accountants, 31 Stoke Grove, Westbury on Trym, Bristol. Tel. Bristol 62-8834.

Office Equipment Exhibition.—Fri., 10 Oct., to Sun., 19 Oct., in Paris. Exhibition offices: 6 Place de Valois, Paris 1er.

Photography, International Exhibition.—Sat., 11 Oct., to Sat., 1 Nov., at the Laing Municipal Art Gallery, Newcastle upon Tyne. Apply to Mr. W. Warburton Pope, 9 Kimberley Gardens, Newcastle upon Tyne, 2.

ELECTRONICS IN THE USA

National Electronics Conference.—Mon., 13 Oct., to Wed., 15 Oct., at the Hotel Sherman, Chicago, Ill., USA. Sponsored by the American Institute of Electrical Engineers, Illinois Institute of Technology, the Institute of Radio Engineers, and the Illinois Northwestern Universities. Offices: 84 E. Randolph Street, Chicago 1, Ill., USA.

Continuous Conveying Equipment, Discussion Meetings on.—Tues. and Wed., 14 and 15 Oct., in Ostend. Held under the auspices of Section II of the Fédération Européenne de la Manutention. Apply to the British National Committee, 94-98 Petty France, London, S.W.1. Tel. ABBey 4961.

***Steelworks Cranes and Their Drivers, Meeting.**—Tues., 14 Oct., to Thurs., 16 Oct., in Chester. Organised by the Iron and Steel Engineers Group of the Iron and Steel Institute, 4 Grosvenor Gardens, London, S.W.1. Tel SLOane 0061.

Building Trades Exhibition.—Tues., 14 Oct., to Sat., 25 Oct., in the City Hall, Manchester. Organised by Provincial Exhibitions Ltd., City Hall, Deansgate, Manchester. Tel. Deansgate 6363.

Textile Machinery and Accessories Exhibition.—Wed., 15 Oct., to Sat., 25 Oct., at Belle Vue, Manchester. Organised by Textile Recorder Exhibitions Ltd., Old Colony House, South King Street, Manchester 2. Tel. Deansgate 6903.

***Baghdad Agricultural and Trade Fair.**—Wed., 15 Oct., to Sat., 15 Nov., at Baghdad. Apply to the office of the Mutassarif of Baghdad Liwa, Baghdad, Iraq. (Postponed.)

Chemical Engineering Exhibition, International.—Thurs., 16 Oct., to Sun., 26 Oct., in Oslo. Apply to Studieselskapet for Norsk Industri, Forskningsveien 1, Blindern, Oslo, Norway.

Hotel and Catering Industry Exhibition, Fifth International.—Sat., 18 Oct., to Wed., 29 Oct., in Paris. Exhibition offices: 13 Rue de Liège, Paris.

Tunis Trade Fair, Sixth International.—Sat., 18 Oct., to Sun., 2 Nov., in Tunis. Organised by the Foire Internationale de Tunis, Palais Consulaire, Avenue Roustan, Tunis.

Directors' and Executives' Exhibition.—Mon., 20 Oct., to Fri., 24 Oct., at the Royal Horticultural Society's Old Hall, Vincent Square, London, S.W.1. Organised by Specialised Exhibitions Ltd., 58 Jermyn Street, London, S.W.1. Tel. HYDe Park 1391.

Recent Developments in Precast Concrete, Symposium.—Tues., 21 Oct., at the Building Centre, 26 Store Street, London, W.C.1. Apply to Concrete Ltd., 16 Northumberland Avenue, London, W.C.2. Tel. WHItehall 5504.

Engineering Industries Association: 11th London Regional Display.—Tues., 21 Oct., to Thurs., 23 Oct., at the Royal Horticultural Society's New Hall, Greycoat Street, and Old Hall, Vincent Square, London, S.W.1. Offices of the Association: 9 Seymour Street, London, W.1. Tel. WELbeck 2241.

Reinforced Plastics Technical Conference.—Tues., 21 Oct., to Fri., 24 Oct., at the Hotel Metropole, Brighton. Organised by the British Plastics Federation, 47-48 Piccadilly, London, W.1. Tel. REGent 2041.

Dairy Show, 72nd Annual.—Tues., 21 Oct., to Fri., 24 Oct., at Olympia, London, W.14. Organised by the British Dairy Farmers' Association, 17 Devonshire Street, London, W.1. Tel. LANgham 6903.

MOTOR SHOW

Motor Show, 43rd International.—Wed., 22 Oct., to Sat., 1 Nov., at Earl's Court, London, S.W.5. Organised by the Society of Motor Manufacturers and Traders, Ltd., 148 Piccadilly, London, W.1. Tel. GROsvenor 4040.

International Road Federation, Third World Meeting.—Sun., 26 Oct., to Fri., 31 Oct., in Mexico City. Offices of the Federation: Abbey House, Victoria Street, London, S.W.1. Tel. ABBey 6177.

Metal Exposition and Congress, 40th National.—Mon., 27 Oct., to Fri., 31 Oct., at the Public Auditorium, Cleveland. Organised by the American Society for Metals, 7301 Euclid Avenue, Cleveland 3, Ohio, USA.

Canadian National Packaging Exposition, Seventh.—Tues., 4 Nov., to Thurs., 6 Nov., in the grounds of the Automotive Building, Toronto. Organised by the Packaging Association of Canada, 1 St. Clair Avenue West, Toronto 7, Canada.

Bottling Exhibition, 12th International.—Tues., 4 Nov., to Thurs., 13 Nov., in Paris. Exhibition offices: 28 Rue Louis-le-Grand, Paris, 9e.

Mechanical Handling Exhibition, International.—Wed., 5 Nov., to Thurs., 13 Nov., in Paris. Apply to the Salon de la Manutention, 40 Rue du Colisée, Paris, 8e.

Packing and Distributing Exhibit, 11th International.—Wed., 5 Nov., to Thurs., 13 Nov., in Paris. Exhibition Offices: 40 Rue du Colisée, Paris, 8e.

Motor Show, 40th International.—Wed., 5 Nov., to Sun., 16 Nov., in Turin. Offices: Corso Galileo Ferraris 16, Turin, Italy.

***Scottish Electro Heat and Productivity Exhibition.**—Mon., 10 Nov., to Fri., 14 Nov., at Kelvin Hall, Glasgow. Organised under the auspices of the South of Scotland Electricity Board, 351 Sauchiehall Street, Glasgow, C.2. Tel. Glasgow Douglas 9955.

PUBLIC WORKS

Public Works and Municipal Services Congress and Exhibition.—Mon., 10 Nov., to Sat., 15 Nov., at Olympia, London, W.14. Organised by the Municipal Agency Ltd., 70 Victoria Street, London, S.W.1. Tel. VICtoria 9132.

***Combustion Engineering Association, Annual Conference.**—Tues. and Wed., 11 and 12 Nov., at the Royal Hotel, Scarborough. *Association's offices:* 6 Duke Street, St. James's, London, S.W.1. Tel. WHItehall 5536.

National Boat Show, 11th Annual.—Fri., 28 Nov., to Sun., 7 Dec., at the National Guard Armory, Seattle. Organised by the Northwest Marine Industries, Inc., Marina Mart, 1500 Westlake Avenue North, Seattle.

American Association for the Advancement of Science.—Fri., 26 Dec., to Wed., 31 Dec., at Washington, D.C., USA. Offices of the Society: 1515 Massachusetts Avenue N.W., Washington 25, D.C., USA.

Boat Show, Fifth National.—Wed., 31 Dec., to Sat., 10 Jan., 1959, at Olympia, London, W.14. Organised by the Ship and Boat Builders' National Federation, 205 Regent Street, London, W.1. Tel. REGent 1108.

***National Motor Boat Show.**—In January, 1959, at the New York Coliseum, New York. Organised by the National Association of Engine and Boat Manufacturers, Inc., 420 Lexington Avenue, New York 17, USA.

***International Toy Fair.**—Sat., 10 Jan., to Fri., 16 Jan., 1959, at Harrogate. Apply to the Harrogate International Toy Fair Ltd., Finsbury Court, Finsbury Pavement, London, E.C.2. Tel. MONarch 8921.

***Housewares Exhibition, National.**—Thurs., 15 Jan., to Thurs., 22 Jan., 1959, in Chicago. Organised by the National Housewares Manufacturers' Association, 1140 Merchandise Mart, Chicago 54, Ill., USA.

Physical Society's Exhibition of Scientific Instruments and Apparatus, 43rd.—Mon., 19 Jan., to Thurs., 22 Jan., 1959, in the Royal Horticultural Society's Old and New Halls, Vincent Square and Greycoat Street, London, S.W.1. Organised by the Physical Society, 1 Lowther Gardens, Prince Consort Road, London, S.W.7. Tel. KENsington 0048.

***Physical Society of America, Annual Exhibition and Convention.**—Wed., 28 Jan., to Sat., 31 Jan., 1959, at the Hotel New Yorker, New York. Organised by the American Institute of Physics, 33 East 45th Street, New York 17, USA.

***Factory Management Conference and Exhibition, 11th.**—Wed., 28 Jan., to Wed., 4 Feb., 1959, at Netherland Hilton Hotel, Cincinnati. Information from Mr. G. B. Albritton, 342 Madison Avenue, New York 17, USA.

***Long-Distance Transmission by Waveguide, Convention.**—Thurs. and Fri., 29 and 30 Jan., 1959, at the Institution's headquarters in London. Organised by the Radio and Telecommunication Section. Apply to the Institution of Electrical Engineers, Savoy Place, Victoria Embankment, London, W.C.2. Tel. TEMple Bar 7676.

***Materials Handling in Canadian Industry Exposition.**—Mon., 2 Feb., to Fri., 6 Feb., 1959, at the Automotive Building, Toronto. Organised by *Materials Handling in Canadian Industry*, 2 Bloor Street East, Toronto 5, Canada.

***New Building Materials and Techniques, Exhibition.**—Fri. and Sat., 6 and 7 Feb., 1959, at the Royal York Hotel, Toronto. Organised by the Ontario Association of Architects, 50 Park Road, Toronto, Ont., Canada.

***National Boat Show.**—Fri., 6 Feb., to Sun., 15 Feb., 1959, in the International Amphitheatre, Chicago. Organised by the Outboard Boating Club of America, 307 North Michigan Avenue, Chicago, USA.

***Canadian Hardware Show, 54th Annual.**—Mon., 9 Feb., to Thurs., 12 Feb., 1959, in the Canadian National Exhibition Grounds, Toronto. Organised by the Canadian Retail Hardware Association, 290 Merton Street, Toronto 7, Ontario, Canada.

***Stationery Trade Fair, Fifth.**—Mon., 9 Feb., to Fri., 13 Feb., 1959, at Alexandra Palace, London. Organised by the Stationers' Association of Great Britain and Ireland, 6 Wimpole Street, London, W.1. Tel. LANgham 9256.

POWER FARMING

***Power Farming Conference, National.**—Tues., 10 Feb., to Thurs., 12 Feb., 1959, at Harrogate. Theme: "Machinery and Men." Organised by *Practical Power Farmer* and the *Farmer and Stock Breeder*, Dorset House, Stamford Street, London, S.E.1. Tel. WATerloo 3333.

***British Hosiery and Knitwear Exhibition.**—Mon., 16 Feb., to Fri., 20 Feb., 1959, at Seymour Hall, London. Organised by Industrial Exhibitions Ltd., 9 Argyll Street, London, W.1. Tel. GERrard 1622.

***Toy Fair.**—Mon., 16 Feb., to Fri., 20 Feb., 1959, at Brighton. Organised by the British Toy Manufacturers Association, 93-94 Hatton Garden, London, E.C.1. Tel. CHAncery 9158.

***Stationery and Book Trades Fair, National.**—Mon., 16 Feb., to Fri., 20 Feb., 1959, at the Royal Horticultural Society's Old and New Halls, Vincent Square and Greycoat Street, London, S.W.1. Organised by the *National Newsagent, Bookseller and Stationer*, 149 Fleet Street, London, E.C.4. Tel. CITy 2604.

***Scottish Dairy Show.**—Tues., 17 Feb., to Fri., 20 Feb., 1959, at the Kelvin Hall, Glasgow. Organised by the Glasgow Agricultural Society, 51 Moss Street, Paisley. Tel. Paisley 6244.

***Alberta Motor Show.**—Tues., 17 Feb., to Sun., 22 Feb., 1959, at the Jubilee Auditorium, Edmonton, Alberta. Organised by the Alberta Motor Show Committee, c/o Edmonton Symphony Society, Hudson's Bay Store, Jasper Avenue, Edmonton, Alberta, Canada.

Melbourne International Trade Fair.—Thurs., 26 Feb., to Sat., 14 Mar., 1959, at the Exhibition Buildings, Melbourne. Organised by the Melbourne Chamber of Commerce, 422 Collins Street, Melbourne.

***Tel Aviv Agricultural Exhibition.**—In March, 1959, at the Beth Dagan Fair Grounds, Tel Aviv. Organised by the Agricultural Exhibitions Co., Ltd., P.O. Box 209, Hakirya, Tel Aviv, Israel.

***Utrecht International Spring Fair.**—*Consumer Goods:* Mon., 9 Mar., to Sat., 14 Mar., 1959, at Utrecht, Holland. *Technical Fair:* Wed., 15 April, to Fri., 24 April, 1959, at Utrecht, Holland. Apply to Mr. W. Friedhoff, Netherlands Chamber of Commerce, 10 Gloucester Place, London, W.1. Tel. WELbeck 9971.

***Automatic Vending Machine Exhibition, First International.**—Tues., 10 Mar., to Fri., 13 Mar., 1959, at the Royal Horticultural Society's Old Hall, Vincent Square, London, S.W.1. Organised by Contemporary Exhibitions Ltd., 40 Gerrard Street, London, W.1. Tel. GERrard 4951. (Change of venue.)

***Oil and Colour Chemists' Technical Exhibition.**—Tues., 17 Mar., to Thurs., 19 Mar., 1959, at the Royal Horticultural Society's New Hall, Greycoat Street, London, S.W.1. Organised by the Oil and Colour Chemists' Association, Memorial Hall, Farringdon Street, London, E.C.4. Tel. CENtral 2120.

***Radio Engineering Show.**—Mon., 23 Mar., to Thurs., 26 Mar., 1959, at New York Coliseum, New York. Sponsored by the Institute of Radio Engineers. Organised by William C. Copp Associates, 72 West 45th Street, New York 22, USA.

California International Trade Fair and Industrial Exposition, First.—Wed., 1 April, to Sun., 12 April, 1959, at the Great Western Exhibit Grounds, Los Angeles, California. Offices: P.O. Box 77610, Station D, Los Angeles 7, California, USA.

FACTORY EQUIPMENT

***Factory Equipment Exhibition.**—Tues., 7 April, to Fri., 17 April, 1959. Also the **Heat and Sound Exhibition.**—Tues., 7 April, to Fri., 17 April, 1959. Both to be held at Earl's Court, London, S.W.5. Organised by Factory Equipment Exhibitions Ltd., 4 Snow Hill, Holborn Viaduct, London, E.C.1. Tel. CENtral 0354.

***National Packaging Exposition, 28th.**—Mon., 13 April, to Fri., 17 April, 1959, at the International Amphitheatre, Chicago. Organised by Clapp and Poliak Inc., 341 Madison Avenue, New York 17, USA.

Films in the Service of Industry, Second Festival.—Tues., 21 April, to Fri., 24 April, 1959, at Harrogate, Yorkshire. Apply to the organising secretary, Mr. R. T. Edom, 3 Portman Chambers, 7–9 Baker Street, London, W.1. Tel. WELbeck 1104.

***Electronic Parts Distributors Show.**—In May, 1959, at the Conrad Hilton Hotel, Chicago. Organised by the Electronic Industry Show Corporation, Suit 1500, 11 South La Salle Street, Chicago 3, Ill., USA.

***Tokyo International Trade Fair.**—Tues., 5 May, to Fri., 22 May, 1959, at Tokyo. Organised by the Economic Bureau, Tokyo Metropolitan Government, Marunouchi, G.P.O Box 1201, Tokyo, Japan.

***United States World Trade Fair, Third.**—Fri., 8 May, to Tues., 19 May, 1959, at the New York Coliseum, New York, USA. *Managers:* The Charles Snitow Organisation, Inc., 331 Madison Avenue, New York 17. Information may be also obtained from the British Commonwealth Chamber of Commerce in the United States, 677 Fifth Avenue, New York 22. The fair's British and Commonwealth office is at 36-38 Southampton Street, London, W.C.2. Tel. TEMple Bar 8947.

***Sydney Machine Tool Exhibition, Second.**—Mon., 11 May, to Sat., 16 May, 1959, at the Show Ground, Sydney. Organised by the Machine Tool Division, Sydney Chamber of Commerce, 36 Grosvenor Gardens, Sydney, Australia.

***Petroleum Exposition and Congress, International.**—Thurs., 14 May, to Sat., 23 May, 1959, at Tulsa. Information from Mr. William B. Way, 2104, Philtower, Tulsa, Oklahoma, USA.

***Transistors and Associated Semi-Conductor Devices, International Convention.**—Mon., 25 May, to Fri., 29 May, 1959, at the Institution's headquarters in London. Organised by the Radio and Telecommunication Section. Apply to the Institution of Electrical Engineers, Savoy Place, Victoria Embankment, London, W.C.2. Tel. TEMple Bar 7676.

***Royal Ulster Agricultural Show, 92nd.**—Wed., 27 May, to Sat., 30 May, 1959, at the King's Hall, Belfast. Organised by the Royal Ulster Agricultural Society, King's Hall, Balmoral, Belfast. Tel. Belfast 665225.

***World Petroleum Congress, Fifth.**—Sat., 30 May, to Fri., 5 June, 1959, at New York Coliseum, New York, USA. Apply to the British National Committee, Institution of Petroleum, 61 New Cavendish Street, London, W.1. Tel. LANgham 3583. (Date settled.)

British Electrical Power Convention.—Mon., 1 June, to Sat., 6 June, 1959, at Torquay. Organised by the British Electrical Power Convention, 26-27 Cockspur Street, London, S.W.1. Tel. WHItehall 1928.

COMBUSTION ENGINES

International Congress on Combustion Engines.—Mon., 15 June, to Sat., 20 June, 1959, at Wiesbaden, Germany. Theme: "Diesel Engines and Gas Turbines up to 1,500 h.p.: Current Problems Concerning Their Design, Production, Development and Running on Site." Apply to the secretary to the national committee, International Congress on Combustion Engines, 6 Grafton Street, London, W.1. Tel. HYDe Park 5107. (Additional information.)

Plastics Exhibition and Convention, International (formerly the **British Plastics Exhibition and Convention**).—Wed., 17 June, to Sat., 27 June, 1959, at Olympia, London, W.14. Organised, with the support of the British Plastics Federation, 47-48 Piccadilly, London, W.1 (Tel. REGent 4681), by *British Plastics*, Dorset House, Stamford Street, London, S.E.1. Tel. WATerloo 3333.

***Safety and Factory Efficiency Exhibition.**—Fri., 19 June, to Fri., 26 June, 1959, at Bingley Hall, Birmingham. Offices: 71 Broad Street, Birmingham 15. Tel. Midland 8073.

Chicago International Trade Fair.—Thurs., 2 July, to Sat., 18 July, 1959, at the Navy Pier Exhibition Hall, Chicago. Organised by the Chicago Association of Commerce and Industry, 30 West Monroe, Chicago 3, Ill., USA.

***Utrecht Autumn Fair.**—*Consumer Goods:* Mon., 31 Aug., to Sat., 5 Sept., 1959, at Utrecht, Holland. Apply to Mr. W. Friedhoff, Netherlands Chamber of Commerce, 10 Gloucester Place, London, W.1. Tel. WELbeck 9971.

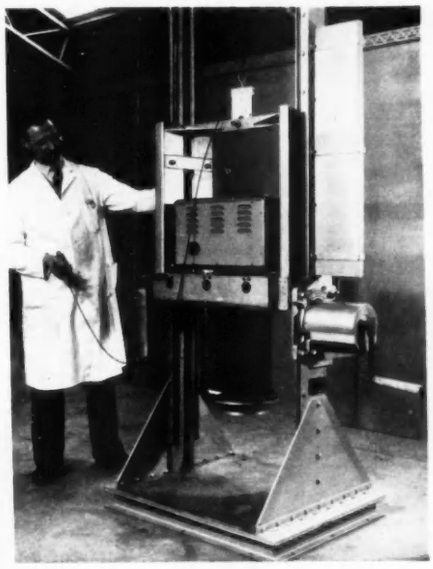
***Scottish Industries Exhibition.**—Thurs., 3 Sept., to Sat., 19 Sept., 1959, at the Kelvin Hall, Glasgow. *Offices:* 2 Woodside Terrace, Glasgow, C.3. Tel. Douglas 9911.

Production

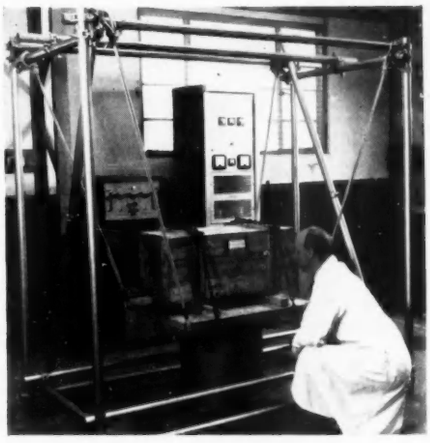
TESTING PACKING METHODS FOR TRANSPORT ANYWHERE

It is not unreasonable to consider the transportation of goods from the factory to the user as part of the production process, and yet it is only within comparatively recent years that the important question of packing for transport has had the attention it deserves. Stimulated by the war-time needs of the Armed Forces, the art of packing has become a science. Its importance in non-military fields is increasing, and here the question of cost is also of particular importance. It is easy, in attempting to safeguard goods in transit, to overpack, and so to waste money in freight charges as well as in the cost of the packing materials themselves. To be a satisfactory protection to the goods, as well as an economic proposition, the package should be designed to suit both the travelling conditions and the goods themselves.

To prepare suitable package designs it is necessary to determine several basic facts about the goods and the effects which various possible hazards may have upon them, and this can only be done scientifically with the aid of special-purpose equipment. Such an installation has now been completed at the Smethwick works of the Salterpak Division of Geo. Salter and Company Limited, West Bromwich, Staffordshire. Started some years ago solely for packing the company's own products, the Salterpak Division has been extended to provide a complete packing service to the trade, for goods of any size or type. With its new equipment now in service, Salterpak can undertake a complete investigation into the production and use of the necessary packing, and can provide full facilities for testing a pack or a packed consignment under any kind of treatment that it is likely to receive; the test equipment can, in fact, reproduce conditions worse than will ever be encountered by a consignment on its travels. Much of the equipment, being of a specialised nature and unobtainable from commercial suppliers, has been designed and built by the company.

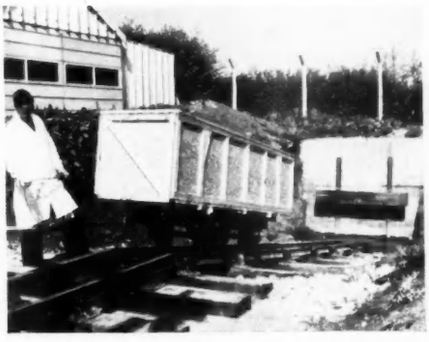


Varying forces and different degrees of cushioning can be applied by this machine.



A product or a package can be vibrated at any required rate up to 10,000 cycles a second.

The effects of transport over rough roads are investigated by a cam operated vibrator giving a 1 in lift every 0·25 sec.



Damage often results from a package swinging against a dock wall. This equipment reproduces the effect for test.

HOW THE PRODUCT BEHAVES

To design a packing, it is necessary to know how the product concerned will behave under various conditions of possible ill treatment, and there are several machines for investigating this problem. One of the hazards of transport is impact, and it is important to know how a particular product will react to the varying degrees of impact it is likely to receive. A fairly simple platform-type drop test machine allows different *g* factors to be applied to an article under test, and the machine is so constructed that cushioning, variable over a wide range, can be applied by means of a compressed air cylinder, at the bottom of the drop. A view of this machine in action is shown in the illustration above.

It sometimes happens that an article will withstand considerable impact, but is damaged by the resonance set up by some external source of vibration during transport, and equipment is accordingly provided for determining the natural frequency of goods which might be susceptible to such effects. In this test, an article is mounted on a suspended table, as shown in the second illustration. The table is then vibrated electrically and controlled electronically to produce any frequency in the range, normally of from 3 to 1,000 cycles per second. Frequencies up to 10,000 cycles per second can be produced if required. Both the machines mentioned above can, of course, be used to test a packed product as well as one which is unpacked, and there are several other machines which, though more specifically intended for testing the packed product, can also be used for investigating the characteristics of the product itself, or for testing empty packs.

THE PACKAGE IN ACTION

When the detailed specification of the pack has been decided upon, and the goods, suitably protected against corrosion or other atmospheric effects where necessary, have been packed, the complete package can be tested in various ways, either to investigate its effectiveness under test to destruction, or to meet test specifications laid down by customers. Shock tests are applied in one of two ways. A pack can be subjected to repeated drops of 1 in at a rate of four drops a second, by means of a cam-lifted platform, which simulates a journey over bad roads or tracks on a vehicle which may have little or no springing. Such a test is shown in process of being conducted in the illustration above.

Packs are also tested by single free drops from a height of 4 ft 6 in, which is the average height of vehicle platforms. An accelerometer is packed with the goods and records, on a cathode-ray tube, the force which is transmitted to the goods themselves; and a photographic record of the cathode-ray trace can be made when required. The effectiveness of the packing is thus determined to close limits.

Another source of shock to which packages

Continuing Production

are often subjected is swinging against the side of a ship or a dock wall while suspended from a crane. To reproduce this effect a rail track is installed on a 10° gradient, and a wagon carrying the package is allowed to run freely down this gradient for a distance of about 29 ft. It then strikes a concrete block, at a speed of about 10 m.p.h. An accelerometer mounted in the pack with the goods records the amount of shock transmitted. The effectiveness of this test is clearly indicated in the reproduction on the previous page.

Shock is not, by any means, the only possible source of damage to goods in transit. Static loading can cause damage when packs are stacked in a ship's hold, or in a warehouse, to such a height that the lower ones are crushed. To test the effective strength of packs of various kinds there is a hand-powered hydraulic press.

CLIMATIC EFFECTS

Slower in their effects than impact, but no less destructive to some products, are extremes of temperature and humidity. A pack may have to withstand these influences, not only while it is travelling to its destination, but while it is being kept in store for a considerable time, and the pack therefore, may have to be effective over a long period—perhaps indefinitely. Various means are used to protect goods against climatic damage, such as cocooning, sealing in plastics bags, plastics coatings and packing with dessicators. All these devices and others, have their uses, according to circumstances. For testing their effectiveness, it is necessary to reproduce any of the world's climates to order. To test the effectiveness of pack waterproofing is simple. A pump sprays the pack with water at 60 lb per sq. in at a rate of 100 gallons a minute for as long as necessary, and, at the end of the period, the effectiveness of the protection is easily judged visually.

High temperature and humidity effects require more elaborate plant to reproduce. A specially-built chamber enables packs to be exposed to temperatures in the region of 95 to 100° F and to 100 per cent relative humidity for any required period. Automatic control permits of temperature and humidity cycling, again as required, and the temperature can be raised to 140° F, if necessary. For dry-heat tests, simulating direct exposure to equatorial sun under desert conditions, there is a second chamber. Here, temperatures of up to 140° F can be held, with relative humidity down to 40 per cent or less.

There are no conditions likely to be met by packages anywhere in the world which cannot be reproduced by Salterpak, and the testing equipment is, of course, backed by full facilities for the production of packs and for packing goods of any size for any travelling conditions. A drawing office is attached to the Division for designing packing equipment to suit particular products and conditions.

TERYLENE CONVEYORS

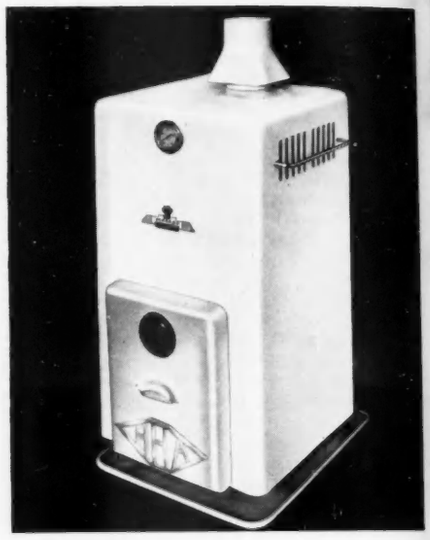
It has recently been announced by Imperial Chemical Industries Limited that deep-trough conveyor belts of rubber-covered Terylene fabric have been giving good service in the firm's fertiliser plant at Billingham. The belts are thinner than is necessary with other materials and require less maintenance; they are also better for handling hot materials.

Engineering at Home

NATURAL-DRAUGHT OIL BURNER

Recently advance details of a new oil-fired domestic boiler were released; the makers wished to give an opportunity for constructive criticism before finalising the jigs and tools for producing the unit. No electric blower, pump, electricity or gas supply is required. The new boiler was well received and about a dozen independent tests by oil heating specialists and oil companies confirmed the designers' claims, which included high efficiency and silent operation. Tooling is now going ahead and production is scheduled for three months delivery.

The production of the new boiler follows several years of experience and research by J. T. Prince Engineering Company Limited—widely known as aircraft sub-contractors and general engineers. The firm is equipped for practically all classes of precision machine work and in addition has for many years specialised in fabricated welded structures.



The natural-draught oilfired boiler is silent in operation and achieves an efficiency of 86 to 88 per cent.

Among the subcontract work carried out were the experimental models and prototypes for a range of American oil-fired space heaters and prototypes for a Continental boiler. This work coincided with the recession in the aircraft sub-contracting field for military aircraft and the firm decided to enter the domestic oil firing market, which was rapidly expanding and offered excellent prospects for anyone marketing a really efficient unit. Three years ago work was started on a Continental type, which would be manufactured under licence, but inherent faults were found in the design and the investigation was discontinued. An independent line was then taken up and a new type of boiler was designed. Outstanding results were achieved and the new company of Bernard Heating Appliances Limited Bel Works Estate, Hampton Road, Feltham, Middlesex, was formed to develop and market it.

The main problem was noisy burners and it was decided that Oilferno Limited should be approached for a 40-50,000 B.t.u. burner of the Blue Flame type. Unfortunately, the firm could not produce the capacity required in that type but after tests with their smaller burner it was decided to design a boiler of 30,000 B.t.u. to incorporate a standard Oilferno N.D.4 burner. At the same time permission was received to experiment on the lines of Oilferno's design with a view to producing a 50,000 B.t.u. unit. Finally, a successful clear burning Blue Flame burner was produced and the boiler design was then completed to accommodate it.

The firm state that from the outset the results were phenomenal; in fact, the efficiencies were too high for sensible application. The burners and boiler were then developed as a unit and finally the present design was established for production. All the modifications were applied to the 30,000 B.t.u. model. The company attribute the main success of the unit to the boiler design which from the start has aimed to accommodate oil burning without back pressure on the burner and to operate without undue losses. Both boilers, Mark 3 and Mark 5, have efficiencies of between 86 and 88 per cent. They are constructed throughout of heavy gauge steel plate—electrically welded, and hydraulically tested at 150 ft head. Both models use natural draught sleeve type burners which are silent in operation. They are thermostatically controlled and burn any make of light domestic fuel oil. A draught breaker is incorporated and the boilers are independent of chimney draught; only a vent is necessary to take away flue gases. Any chimney free from down draughts is suitable. Adjustable louvres, operated by a towel rail, give convection heating in the kitchen. The prices of the boilers, including controls, draught breaker, and base tray, are: Mark 3 £87 10*s*. and Mark 5 £115.

The Characteristics of the Natural-Draught Boilers

	Mark 3	Mark 5
Rating	30-33,000 B.t.u.	50-53,000 B.t.u.
Stack temp.—		
High fire	325° F	325° F
Low fire	122° F	126° F
CO_2 content—		
High fire	13·5 per cent	13·5 per cent
Low fire	3-3·5 per cent	2·5-3 per cent
Capacity—		
Hot water only	24-45 gal	37-70 gal
Radiators only (including unlagged pipes)	210 sq. ft	320 sq. ft
Consumption—		
High fire	1·9 pts per hour, maximum	3 pts per hour, maximum
Low fire	Less than 0·2 pt	Less than 0·33 pt
Height over flue	41 in	45·5 in
Water capacity	9·5 gal	12·5 gal
Heating surface	11 sq. ft	14 sq. ft
Approx. weight	3 cwt	4 cwt

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